# Stream health assessments

## A comparison of stream health assessments using scientific and cultural indices in the Te Arawa/Rotorua Lakes region


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BAY OF PLENTY REGIONAL COUNCIL

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Cover Photo: Alastair Suren
Memorial arches leading into the village of Te Whakarewarewa. Generations of children belonging to this village have dived for pennies in the Puarenga Stream. It is this long connection with the river that has fuelled a desire to see this stream once again safe for swimming.

# Contents

# Acknowledgements

The authors wish to acknowledge the assistance of Peter Staite in conducting the Cultural Health Index (CHI) assessments at each of the sites. Funding for the study came from Nick Zaman (Pollution Prevention), Kataraina Belshaw (Kotahitanga Strategic Engagement) and Rob Donald (Science) which we are grateful for. Review comments were received from Gail Tipa which we are also grateful for.

# Executive summary

This study examined the use of a CHI to assess Māori cultural values in streams throughout the Te Arawa/Rotorua Lakes region, and compared cultural assessments to those derived using western science-based biological indices. Although a CHI has been developed for nationwide use (Tipa and Tierney 2006), to our knowledge this is the first time that their methodology has been trialled in the Bay of Plenty region.

There are three components of a CHI, including the site status, mahinga kai status, and a cultural stream health measure (CSHM). The site status component assesses the significance of the site to Māori to one of four classes, depending on a sites traditional significance, and whether iwi would return. The mahinga kai component scores the ability of a site to provide traditional food sources, both currently and traditionally, as well as whether iwi can gain access to a site and whether they would return there. The CSHM assesses eight indicators describing physical conditions of a site such as water quality, instream conditions, and riparian conditions/land use. The CSHM is regarded as an objective and accurate reflection of tangata whenua evaluations of overall stream health (Tipa and Tierney 2006), so this study focused on the CSHM.

The CSHM was initially developed for streams in Otago and Canterbury, and has been trialled in Hawkes Bay. However, large differences may exist between iwi and their traditional associations with waterways, and between environmental conditions between streams in the Bay of Plenty and streams in Otago and Canterbury. Because of these differences, we tested the applicability of both the generic CSHM, as well as a number of CSHM scores specific to the Bay of Plenty, based on data from 17 surveyed indicator components.

We compared CSHM scores and a number of biotic metrics obtained from the Council's State of Environment invertebrate monitoring programme, and one-off invertebrate collections from 37 sites throughout the Te Arawa/Rotorua lakes region. We found highly significant relationships between a number of biotic metrics and the generic CSHM (using eight indicators), and also a Bay of Plenty CSHM developed based on the average of all 17 indicators assessed. These results suggest that over the streams sampled, both the CSHM and the Macroinvertebrate Community Index (MCI) were ranking streams from healthy to unhealthy in a similar way.

Following this broad-scale comparison, we compared similarities of the CSHM and biotic metrics in the Puarenga Catchment. This catchment was selected as land use activities there are known to have adverse effects on cultural values. Examination of similarities between the CSHM and biotic metrics from sites here showed no significant correlations. This result highlights important differences between western science and Māori cultural health assessments. For example, from a western science point of view, the effect of a contaminant will decrease as it is diluted, whereas from a Māori perspective, its impact will persist throughout the catchment, irrespective of the degree of dilution. This finding reflects the reductionist approach of western science and how it views biophysical processes in streams, in contrast to the more holistic approach of ki uta ki tai (from the catchment to the sea) held by Māori.

Despite these differences, there is considerable scope and opportunity for wider uptake of the CHI throughout the region. The challenge ahead lies with incorporating the CHI into the Council's Regional Water and Land Plan (RWLP). However, similar challenges currently exist with the use of biological indicators that assess stream health, which despite their widespread use have not been specifically used in the RWLP. This omission should be corrected, particularly in lieu of the recent National Policy Statement for Freshwater that states that councils have an obligation to maintain or improve ecosystem health.

It should thus be possible to develop target MCI values for different water bodies throughout the region that could be built into consent conditions that, for example, ecological health as measured by MCI should not decline by more than a certain amount (or not at all) by a particular activity. Similar processes could be used for cultural values such as the CSHM, with due consideration given by the council of tangata whenua values when writing resource consent conditions to ensure that cultural values do not decrease by more than a certain amount (or not at all).

Use of the CHI, and in particular the CSHM, would enable specific and measurable cultural targets to be set in order to help protect the mauri of surface waters throughout the region. An additional feature of the CSHM approach, as opposed to the use of biotic indicators, is the fact that whakapapa plays an important role in the assessment of a streams cultural value, and that it should be possible to compare a particular waterway's historic cultural values with its contemporary values. Ideally, policies, plans, methods and rules that form part of the RWLP, as well as consent conditions would ensure that any loss of mauri to a waterway is minimised. In this way the overarching objectives, policies and methods of kaitiakitanga as outlined in the RWLP can be achieved.

Finally, it is recommended that a CHI monitoring programme be established by Bay of Plenty Regional Council (BOPRC) to help fulfil a number of initiatives. Firstly, it would provide useful information to the Rangitāiki River Forum of the current and historical values of waterways throughout the Rangitāiki Catchment. Secondly, it would allow for a consistent and reproducible assessment of selected waterways throughout the region to be established. Such work would contribute significantly to the Council’s stated desire of strengthening links with iwi throughout the region, and is likely to result in better, more transparent resource management decisions for all.

# Part 1: Introduction

Freshwater resources within New Zealand are under increasing pressure from activities such as land use change and intensification, water abstraction, and damming for either hydroelectric generation or irrigation (MfE, 2007; Wright, 2013). Under the Resource Management Act (1991), regional councils have a statutory obligation to, amongst other things, monitor the state of, and trends in the environment (s35), as well as to monitor the effectiveness and efficiencies of policies, rules, or methods (s35 (2) (b) and s35 (2A). The most common environmental monitoring programmes run by councils include both water quality and ecological monitoring.

Measures of water quality include parameters such as dissolved oxygen, temperature, pH, nutrients, suspended sediments and/or clarity, and bacteriological contamination. Other commonly measured metrics include a wide range of heavy metals and/or toxicants should the need arise. Water quality parameters are favoured by councils due to their ease of collection, relative ease and cost effectiveness of analysis, and the fact that numeric guidelines and trigger values exist for a specific parameters (e.g., ANZECC, 2000). Many of these trigger values are set for the protection of a specified level of protection (e.g. 80 or 95%) of aquatic organisms. More recently, the draft National Policy Statement for Freshwater Management (NPSFW) has developed proposed national objectives for a range of variables for regional councils to monitor (MfE, 2013). Part of these national objectives includes a banding or grading system as well as introducing national bottom lines, or numerical values for specific variables that cannot be exceeded. Relevant parameters for rivers include variables for rivers such as nitrate, dissolved oxygen, *E. coli*, and chlorophyll a biomass.

Ecological monitoring most commonly involves assessing periphyton cover and biomass, macroinvertebrate and fish communities. Specific guidelines exist for maximum periphyton cover/biomass for the protection of specific values such as maintenance of benthic biodiversity, trout habitat, or angling (Biggs, 2000). For macroinvertebrate communities, metrics such as the Macroinvertebrate Community Index (MCI) or its quantitative version (QMCI), or the number or percentage of Ephemeroptera (Maylfies), Plecoptera (Stoneflies) and Trichoptera (Caddisflies) (EPT) are often used to assess stream health (Boothroyd and Stark, 2000; Stark, 1985; Stark and Maxted, 2007b) and to monitor changes in health over time.  These insect taxa are especially sensitive to the effects of land use changes, and are often reduced in number in streams draining pasture or urban catchments and to monitor changes in health over time.

Finally, predictive methods such as the fish index of biotic integrity (IBI) have been used to describe stream health based on fish communities in relation to suitable reference sites (Joy and Death, 2000). All these scientific methods are based on objective and quantifiable measurements which can be collected using reproducible methods for components such as algae (Biggs, 2000; Joy et al.2013), invertebrates (Stark et al.2001), fish (Joy et al.2013), and instream habitat (Harding et al.2009). All these assessments are thought to provide good overall representations of different components of overall "stream health".

Both water quality and ecological monitoring are done to see whether the current state of a particular water body is inconsistent with the values placed on it. There is, therefore, an implicit assumption that the values of specific waterways have been, or can be defined. An important value that has often been overlooked by regional councils in the management of freshwater concerns that of cultural values of iwi, and their relationship to water. That this has been overlooked is at odds with Part 2 of the RMA, and in particular sections 5, 6, 7 and 8 which aim to protect the rights of tangata whenua.

Under these sections, all persons exercising functions and powers under the RMA in relation to managing the use, development, and protection of natural and physical resources (such as regional councils), shall have particular regard to Māori and their relationship to the land and the environment through the protection of customary rights, kaitiakitanga, the Treaty of Waitangi, and the relationship Māori have with their culture, traditions, ancestral lands, waterways and waahi tapu.

## 1.1 Cultural health assessments

Māori cultural health index assessments have been developed as an alternative approach to assessing stream health (Tipa and Tierney, 2003; 2006). Underpinning the cultural values intrinsic to tangata whenua is that of the life giving force and spiritual concept of mauri. A central concept of mauri is that all things in the natural world are interconnected, and that life supports life. Water is the sustaining element for all life, and if the mauri of streams, lakes and the ocean are affected to a detrimental and unsustainable level, then society as we know it must also be similarly affected. Māori cultural health indices are designed, in part, to try and encapsulate this essence of mauri in a simple, numerical way.

The CHI is comprised of three components:

1 The site status, identifying whether it is of traditional significance to tangata whenua and whether tangata whenua would return to the site in future.

2 Mahinga kai, recognising that mauri is tangibly represented by the physical characteristics of freshwater resources including its fitness, cultural usage and productive capacity.

3 The cultural stream health measure (CSHM), based on assessing individual indicators. This is regarded as an objective and accurate reflection of tangata whenua evaluations of overall stream health (Tipa and Tierney 2006).

Unlike western scientific methods which identify and measure individual aspects of "stream health", cultural assessments consider a more holistic approach to stream health, and recognise that the combined is greater than the sum of the individual components. It is arguable that cultural methods are also more subjective than western science assessments, and based on not only current observations of conditions at a site, but also based on collective in-depth experience of different iwi/hapū groups who have had intergenerational experience with a particular waterway.

The first CHI developed in New Zealand (Tipa and Tierney 2003) was based on research undertaken on a number of rivers in Otago (the Taieri and Kakanui). Two South Island runanga (Otakou and Moeraki) of Ngāi Tahu were involved in identifying indicators and undertaking field assessments of selected indicator variables deemed important to Māori. The original CHI assessed 29 indicators for the CSHM at each site, but this was reduced to only a core set of only five indicators. The five-indicator CSHM was highly correlated with a number of western scientific measures of stream health including the MCI, and the community based SHMAK assessments (Biggs et al.1998) that gave both habitat and invertebrate scores. Tipa and Tierney (2003) highlighted these strong relationships between the MCI and the CSHM, and emphasised that the MCI was based entirely on stream invertebrates, whereas the CSHM had no invertebrate component in assessing stream health from a Māori perspective.

Tipa and Tierney (2006) then recognised the need to validate the CHI in streams other than Otago, and tested the application of the CHI to other rivers in the rohe of Ngāi Tahu (the braided Hakatere/Ashburton River) as well as the Tukituki River in Hawke's Bay, in the rohe of Ngāti Kahungunu. They wanted to know whether different iwi would still use the three overall components of the CHI, and whether different indicators would need to be assessed for the CSHM.

Although they found an overall acceptance of the use of the three components of the CHI, they modified the indicators for their five-indicator CSHM, and instead selected eight indicators that covered catchment, riparian and instream factors. They suggested that this new CSHM could be used as a generic cultural health measure throughout the country. Since then, two other studies have explicitly examined the performance of the CHI in other locations. Harmsworth et al. (2011) examined linkages between cultural and scientific indicators of stream health in 25 sites in the upper South island, using a modification of the CHI as developed by Tipa and Tierney (2006). Here, they used seven of the eight indicators identified by Tipa and Tierney, but also included three others.

Each indicator was assigned a score of 1 to 5, and their overall assessment of the CSHM calculated as the average of the scores. They found significant relationships between their CSHM measures and invertebrate metrics MCI and QMCI and the percentage native vegetation in the catchment. They concluded that cultural indicators could be used in a similar manner as scientific indicators to set environmental benchmarks.

A slightly different study was conducted at two sites in the Whanganui River, where Farquhar (2012) compared relationships between CHI assessments and assessments of stream habitat quality, made using the Stream Ecological Valuation (SEV) protocol (Rowe et al.2008). This study showed similarities between assessments of stream condition using both methods, suggesting that the CHI was comparable to western science methods of both ecological condition and stream habitat condition. It also highlighted the fact that the CHI provided a significant amount of historical and cultural information that is not collected using methods such as the SEV. For example, the CHI identified streams which had considerable historic mahinga kai value, but which now had much less value.

## 1.2 Bay of Plenty study

There are estimated to be over 100 iwi found throughout New Zealand, so it is likely that the CHI protocols, and in particular the choice of indicators for the CSHM developed for the South Island, may need to be modified for use in other parts of the country.

This is particularly pertinent given the large differences in both traditional associations with waterways and iwi groups, and inherent environmental differences based on climatic, geological, topographic and land-cover factors. Thus any form of cultural health assessment developed for other areas in New Zealand may need to consider these inherent potential differences.

This was the rationale behind the Tipa and Tierney (2006) report that examined similarities in the CHI (and in particular the CSHM) between South Island streams, and the Tukituki River in the North Island. Although they found a large degree of similarity between indicators in all regions, and although they developed a generic CSHM, it is still not known whether their generic CSHM would work in other streams throughout the country. In particular, most of the South Island streams and the Tukituki River are braided gravel-bed rivers, and these are often not found in other parts of the North Island, such as in the Bay of Plenty.

The Bay of Plenty region is located in the mid-region of the east coast of the North Island of New Zealand, running from Cape Runaway in East Cape to Waihī Beach in the west. It covers an area of 21,836 $km^2$, and extends inland up to 130 km to the headwaters of the Rangitāiki River, and also includes the Te Arawa/Rotorua Lakes. Large climatic and geological gradients exist within the Bay of Plenty.

Rainfall is generally very high in the western regions near the Kaimai ranges, and much lower in the central and southern regions and in the upper parts of catchment such as the Rangitāiki. Catchment geology is dominated by hard sedimentary greywacke geology east of the Rangitāiki River, and by thick deposits of volcanically derived pumice material that originated during some of the many historic volcanic eruptions. Streams in the eastern part of the region are thus generally gravel bed and somewhat braided in nature, while streams in the more easily eroded pumice geology of the central and Western Bay of Plenty are usually single thread channels.

As its name suggests, the Bay of Plenty is rich in natural resources, and has large areas of native forest and bush, plantation forestry, pasture agriculture (dairying, beef and sheep) and horticulture. Horticulture and dairying are located on fertile land in the Western Bay of Plenty and low-lying coastal plains, while forestry dominates the less fertile areas in the south and south-east. Large areas of native bush occur along the south eastern ranges, and the Kaimai ranges to the west of Tauranga.

Many of the adverse effects of land use are evident in streams and waterways around the region, where urbanisation, dairy farming and forestry have had large impacts on both stream and lake health. The challenge faced by the Bay of Plenty Regional Council (BOPRC) is to allow the continued economic growth within the region whilst minimising further environmental degradation, and loss of intrinsic values that freshwater ecosystems bring to the region.

The Te Arawa/Rotorua Lakes region is typical of many other parts of the Bay of Plenty region, with a large amount of land use intensification and human activities adversely affecting waterway values. One of the larger catchments in Rotorua is the Puarenga. This has been settled predominantly by the hapū of Tuhourangi and Ngāti Whakaue from the Te Arawa wakaiwi for over 20 generations (Lee 2012). The Puarenga is regarded as "Taonga Tuku iho" of special significance, and in its natural clean state had held great mauri and life-giving provisions, which provided benefits to those who lived along its banks (Lee 2012). However, urbanisation, along with the associated growth of industry within the Rotorua region over the years has meant the mauri of the Puarenga Stream and catchment has declined to a point where the gathering of traditional food sources is no longer available. What was once a food basket for local iwi is now regarded by some as desolate, and currently unsustainable for life forms that once inhabited the area.

Like most councils, BOPRC monitors water chemistry and invertebrate communities as part of their State of Environment monitoring. To date, however, no attempt has been made to incorporate cultural aspects into river and stream monitoring, despite the promising results of Harmsworth et al (2011) and Farquhar (2012). Recently, tangata whenua raised concerns with BOPRC about the quality of Puarenga Stream, and in particular about the effects of contaminants on the health of the Penny Divers at the Whakarewarewa bridge. In response to these concerns, BOPRC undertook scientific monitoring of both water and sediment quality of streams in the catchment.

This monitoring identified a number of potential activities in the catchment that may have been having adverse effects including stormwater from the Red Stag timber mill, irrigation of treated sewerage into parts of the Whakarewarewa Forest by the Rotorua District Council (RDC), potential leachate from a RDC landfill, and diffuse runoff from a number of dairy farms in the upper catchment.

The Tuhourangi Tribal Authority has also undertaken CHI assessments of waterways in this catchment (Staite and Lee, 2013). These assessments, coupled with known historical records, have generally shown the Puarenga River cannot support the life that it once did, and that cultural values associated with the Penny Divers which once played a crucial role in the psyche of all Te Arawa post-European settlement are being lost as their numbers have declined due to concerns about water pollution. However, little ecological monitoring has been conducted in this catchment, meaning that any commonalities between the two potentially complimentary methods of CHI and western science have not yet been assessed. It is within this paradigm of traditional western science and traditional cultural knowledge that this work was first discussed as a collaborative study to bring our two seemingly diverse understandings of the environment together.

There were three major objectives for this study:

1. Examine relationships between western science-based ecological methods at assessing stream health and traditional Māori cultural health assessments.
2. Assess the state of a number of streams in the Puarenga Catchment using both scientific and cultural assessments to identify similarities or differences.
3. Assess the feasibility of using assessment methods such as the CHI to help set limits and direct policy for management of freshwaters.

# Part 2: Methods

## 2.1 Study sites

The study was conducted in 37 sites around the Rotorua/Te Arawa Lakes region, located in the western-central area of the Bay of Plenty (Figure 1). The River Environment Classification (REC); (Snelder et al.1998) was used to obtain information about relevant environmental parameters known to influence biological communities at each site.

Most of the streams (20) were of medium size (order 3 and 4) while 13 were small (order 1 and 2). Only four streams were from orders 5 and 6. Two-thirds of the streams were in the cool-wet climate class, while the other third were in the warm-wet class. Dominant catchment land use in these streams included pasture (15 streams), urban (11 streams) and indigenous forest (eight streams). Only three streams drained catchments dominated by exotic pine plantations.

The Department of Conservation (DOC) Freshwater Environments of New Zealand (FWENZ) database was used to determine the percentage land cover of native bush, exotic plantation forests, pasture and urban areas upstream from each of the 37 sites. Percentage land cover data of these four cover classes was converted to a single index (called LAND_INDEX) such that:

- LAND_INDEX = [(0.8* native bush) + (0.6* plantation forest) + (0.4*pasture) + (0.2* urban areas)].

The coefficients for each land cover class were based on the fact that stream health is generally highest in streams draining native bush, and lowest in streams draining urban areas (Clapcott et al. 2011; Hall et al. 2001; Quinn and Cooper, 1997; Suren and Elliot, 2004). Theoretical scores for LAND_INDEX range from 80 (all the catchment in indigenous bush) to 20 (all the catchment in urban areas).

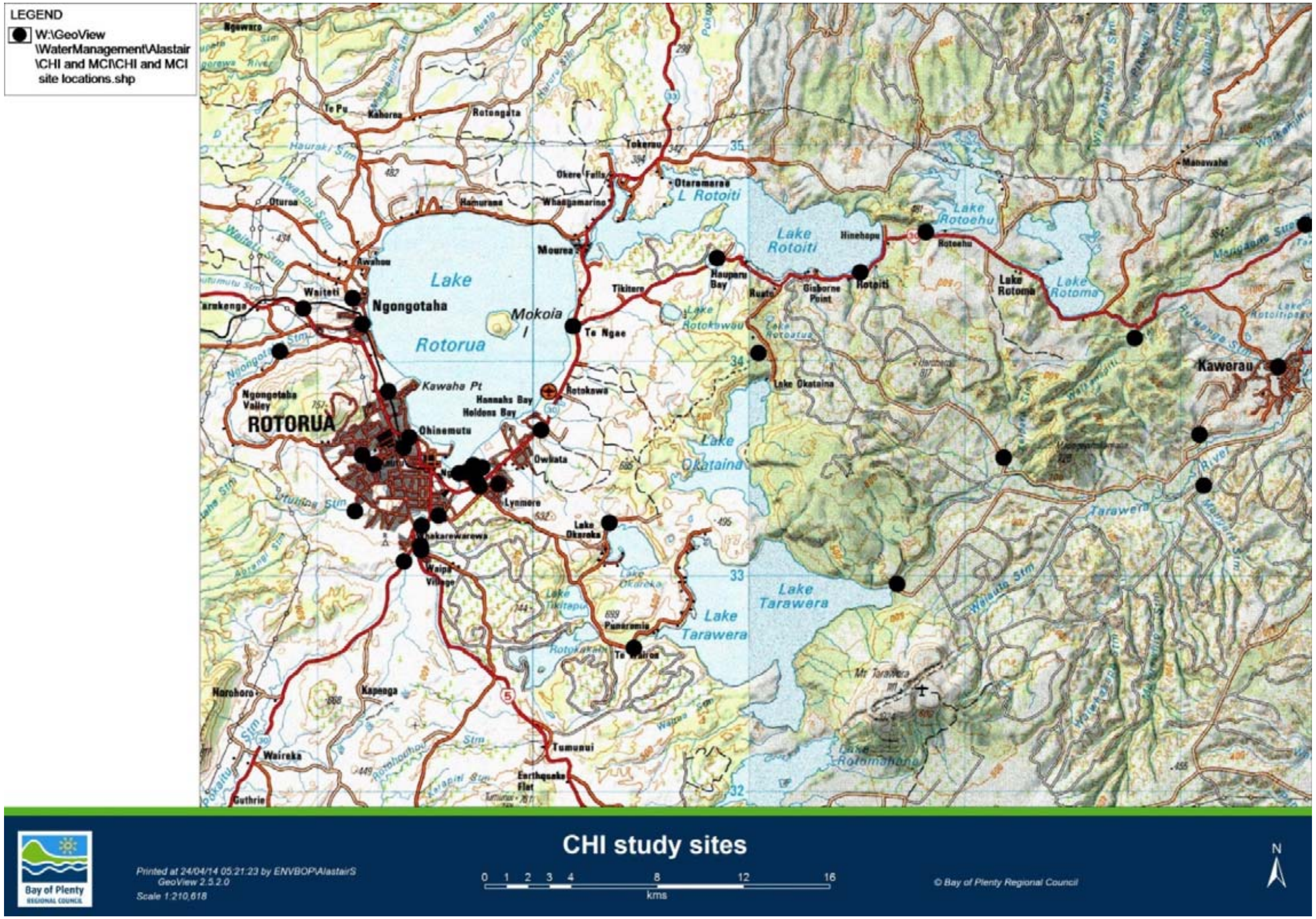



Figure 1 Location of the 37 study sites in the Rotorua region, and the surrounding Te Arawa/Rotorua Lakes region.

## 2.2 Scientific methods

### 2.2.1 Habitat assessments

At each site, habitat assessments were made using a mixture of quantitative and categorical methods (Table 1). For quantitative measurements, five transects were selected at equally spaced distances up the study reach - defined as 20 times the stream width.

At each transect, measurements were made of stream-width, and of water depth and depth of the fine sediment at ¼, ½ and ¾ across the channel. Measurements were also made of the degree of bank undercutting, and of the distance into the stream of overhanging vegetation. These two parameters were measured as overhanging banks represent important habitat for fish such as eels, and overhanging vegetation can provide cover and stream shade. Substrate size was assessed using the (Wolman, 1954) technique, and the resultant percentage cover of the different substrate classes was converted to a substrate index (Jowett, 1993), which ranged from 0.1 (sand or silt dominated) to 0.8 (bedrock dominated).

Hydraulic habitat diversity was assessed by calculating the number, and percentage of riffles, runs or pools up the study reach. Finally, assessments were made of ten categorical habitat parameters including: stream shade; bank stability; the width, intactness and vegetation composition of bankside and riparian buffers; and overall stream habitat diversity. Where relevant (e.g., for bank stability and bankside vegetation), assessments were made of these parameters on both left and right banks. All categorical parameters were divided into five classes, each of which were assigned a specific score (1, 5, 10, 15 and 20). These scores were summed to create an overall stream habitat score (HABSCORE), with a theoretical range of 22 to 440.

*Table 1 List of all habitat variables measured at each of the 37 streams. Quantitative variables were measured at five transects placed across the stream, or were an assessment of the whole stream, while categorical variables were measured along the whole length of the stream, or its riparian area along the stream's left or right banks.*

| Variable type | Measured factor | Measured where |
|---|---|---|
| **Quantitative** | Stream width | 5 transects |
| | Stream depth | 5 transects (at three locations per transect) |
| | Degree of bank undercutting | Left and right banks at 5 transects |
| | Overhanging vegetation | Left and right banks at 5 transects |
| | Fine sediment depth | 5 transects (at three locations per transect) |
| | Substrate index | Whole stream |
| | Flow diversity | Whole stream |
| | % riffles, runs, pools | Whole stream |
| **Categorical** | Groundcover of buffer vegetation | Left and right banks |
| | Width of bankside buffer vegetation | Left and right banks |
| | Buffer intactness | Left and right banks |

| Variable type | Measured factor | Measured where |
|---|---|---|
| | Composition of streamside vegetation | Left and right banks |
| | Stream shading | Left and right banks |
| | Bank stability | Left and right banks |
| | Stock access | Left and right banks |
| | Stock damage | Left and right banks |
| | Instream diversity | Whole stream |
| | Land slope 0 to 30 m from the stream bank | Left and right banks |

### 2.2.2 Ecological assessments

Semi-quantitative invertebrate samples were collected from each study site in the summer-autumn of 2013. Some of the streams were sampled as part of the BOPRC's ongoing State of Environment monitoring, while other sites were sampled specifically for this assessment.

In hard-bottomed streams (i.e., dominated by cobbles and gravels), invertebrates were sampled from different habitats in proportion to their percentage occurrence using a kick-net and by dislodging the streambed material upstream of the net and collecting all dislodged material (invertebrates and organic matter) in the downstream net (i.e., Protocol C1 of Stark et al 2001).

In soft-bottomed streams, Protocol C2 (Stark et al 2001) was used whereby woody debris, submerged logs and aquatic macrophytes, and bankside vegetation were sampled in proportion to their percentage occurrence. Only a single pooled sample was collected from each site for all kick sampling of hard and soft-bottomed streams. Approximately 1 $m^2$ of stream bed or organic material was sampled.

All material was placed into appropriately labelled plastic bottles and preserved with isopropyl alcohol prior to processing. Samples were processed by a modification of Protocol P2, where a fixed count of 200 invertebrates was used. The modification used was to first sieve the contents of each sample through a 0.5 mm sieve, and then examine the contents of each sieve separately. This was done to minimise any bias towards only collecting and counting larger specimens. All invertebrates were identified down to genera, or levels of taxonomic resolution consistent with that of Stark (1996).

### 2.2.3 Cultural methods

The original CHI assessed as developed by Tipa and Tierney (2003) assessed three components of relevance to Māori:

1 The traditional association of the site to Māori.

2 Maintenance of mahinga kai resources. This involved assessing amongst other things the:

   (a) presence and abundance of mahinga kai species at a site,

   (b) the ability to harvest the same species as in the past from sites of traditional significance,

   (c) the ability to access a site,

   (d) the perception that the sites can be used as had been in the past.

3 A cultural stream health measure, itself made up of a number of different indicators.

Tipa and Tierney (2003) originally developed field sheets that collected data of 26 different indicators, of which 11 could be considered of relevance to mahinga kai, and 15 of relevance to the calculation of an overall cultural stream health measure (Table 2). They then identified and recommended the use of five of these 26 indicators that were considered the most important to calculate a cultural stream health measure (Table 2). More recent work as part of the development of a nationwide CHI led them in 2006 to create a generic CSHM that used eight indicators (Table 2), including the five originally recommended, plus three others (riparian vegetation, water clarity and riverbed condition/sediment).

Large differences in iwi traditions, cultural connection to waterways, and environmental differences between stream types throughout the country means that the generic CSHM of eight indicators as suggested by Tipa and Tierney (2006) may not simply be relevant for the rohe of Ngāti Awa to assess the cultural health of waterways around the Rotorua Lakes. As part of their 2006 study, Tipa and Tierney assessed stream health in the Tukituki catchment in Hawke's Bay using 17 indicators for the CSHM (Table 2). These same indicators were thus selected for this study. In particular we wanted to see whether the generic Tipa and Tierney CSHM based on eight indicators could be used in the Bay of Plenty, or whether instead a modified CSHM of more, or less indicators needed to be created.

## 2.3 Statistical analysis

All invertebrate data consisted of a large data matrix of all the different invertebrates found at the 37 sites. This data was converted to percentages and then examined for normality and log (x+1) or fourth-root transformed where necessary. A number of biotic metrics were calculated to describe aspects of the invertebrate community, including the macroinvertebrate community index (MCI) and its quantitative variant (QMCI: Stark, 1985; Stark and Maxted, 2007a), as well as the number and percentage of Ephemeroptera, Plecoptera and Trichoptera (EPT).

These insect taxa are especially sensitive to effects of land use changes, and are often reduced in number in streams draining pasture or urban catchments (Hall et al.2001; Meyer and Meyer, 2000; Quinn, 2000; Suren, 2000). Next, the statistical technique of ordination was used to simplify the large matrix of invertebrate data into a simple two dimensional space, so that any patterns in the data could be visualised. In this way, sites with similar species composition were plotted close together, and sites with dissimilar species were placed far apart. For this analysis, Detrended Correspondence Analysis (DCA) ordination was used (McCune and Mefford, 1997). Regression analysis was used to determine which invertebrate taxa and measured environmental variables were significantly related to the resultant ordination scores. In this way it was possible to determine which taxa and environmental variables were associated with any gradients observed in the data. For example, positive correlations for a particular invertebrate taxa for the Axis_1 ordination scores means that the abundance of this taxa increases in samples with high Axis_1 scores.

*Table 2 List of all the indicator attributes used in the development of a cultural stream health measure by (Tipa and Tierney (2003) and (2006)), and in the present study.*

| | Original draft CSHM (Tipa & Tierney (2003)) | | Recommended variables (Tipa & Tierney (2003)) | Generic CSHM (Tipa & Tierney (2006)) | This study |
|---|---|---|---|---|---|
| CSHM | 1 | Catchment land use | Catchment land use | Catchment land use | Catchment land use |
| CSHM | 2 | Riverbank condition | | | Riverbank condition |
| CSHM | 3 | River shape | | | |
| CSHM | 4 | Riparian vegetation | | Riparian vegetation | Riparian vegetation |
| CSHM | 5 | Indigenous species | | | Indigenous species |
| MK | 6 | Mahinga kai species (birds) | | | |
| CSHM | 7 | Riverbed condition | | | Riverbed condition |
| CSHM | 8 | Channel modifications | Channel modifications | Channel modifications | Channel modifications |
| CSHM | 9 | Use of the river (takes or discharges) | | | Use of the river (takes or discharges) |
| CSHM | 10 | River flow (movement) | River flow | Flow and habitat variety | River flow (movement) |
| CSHM | 11 | River flow (sound) | | | |
| CSHM | 12 | Water quality (odours) | | | |
| CSHM | 13 | Water quality (pollution) | Water quality | Water quality | Water quality (pollution) |
| CSHM | 14 | Water clarity | | Water clarity | Water clarity |
| CSHM | 15 | Sediment | | Riverbed condition/sediment | |
| CSHM | 16 | Use of riparian margin | Use of riparian margins | Use of riparian margins | Use of riparian margin<br><br>A variety of habitats |
| MK | 17 | Feeling safe – tasting | | | Feeling safe – tasting |
| MK | 18 | Would you fish here? | | | Would you fish here? |
| MK | 19 | Feeling safe - eating fish | | | Feeling safe - eating fish |
| MK | 20 | Balance between land and river | | | |
| MK | 21 | Abundance of birds | | | |
| MK | 22 | Diversity of birds | | | |
| MK | 23 | Abundance of plants | | | |
| MK | 24 | Diversity of plants | | | |
| MK | 25 | Access to the site | | | |
| MK | 26 | Suitability for harvesting mahinga kai | | | |
| MK | | | | | Feeling safe - swimming |
| MK | | | | | Food Sources present |
| Overall | Overall health | | | Overall health | Overall health |

The generic CSHM was calculated for all streams based on the eight indicators identified by Tipa and Tierney (2006). However, because this was the first time that the CSHM had been trialled in the Bay of Plenty, it was decided to create four new versions of the CSHM to see whether these performed any better than the generic CSHM. The first version (called CSHM_BoP) was developed using the same methodology as outlined by Tipa and Tierney (2006):

1 For each of the 12 indicators assessed, rate them from 1 to 5.
2 Assess the overall stream health at each site. This assessment provides a subjective and holistic score of stream health.
3 Identify relationships between individual indicators and the overall holistic assessment of stream health by correlation analysis.
4 Remove any indicators that are highly correlated.
5 Use stepwise multiple regression (SMR)[1] to identify indicator variables that best help explain the overall stream health, and use selected variables to calculate the final CSHM_BoP.
6 Assess the performance of the CSHM_BoP by comparing this to western science measures, including all biotic metrics and the HABSCORE.

We also created three more CSHM scores to see whether they showed stronger relationships to western metrics than either the CSHM or the CHSM_BoP. The first of these indices (called $CSHM\_{All}$) was calculated as the average of all 12 individual CSHM indicators. The other two indices were based on results from a forwards ($CSHM\_{forward}$) and backwards ($CSHM\_{backward}$) stepwise multiple regression of all 17 of the indicator variables measured at each site, including both CSHM and mahinga kai variables against the holistic assessment of stream health.

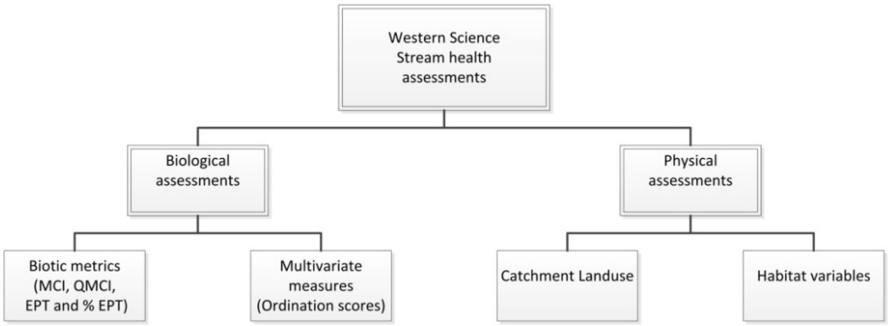
[1] Stepwise multiple regression (SMR) analysis is a statistical technique used to determine which of many individual predictor variables are significantly correlated to a single dependent variable. The goal of a SMR is to choose a small subset of predictor variables from a larger set so that the resulting regression model is simple, yet has good predictive ability. There are two forms of SMR:

1. Forward SMR looks at the correlation of each predictive variable in turn against the dependent variable, and selects the variable with the strongest predictive power to enter the model. It then repeats this process looking at the correlation of the remaining predictive variables, and adds the next strongest predictive variable to the model.
2. Backwards SMR looks at the correlation of all predictive variables in a combined model against the dependent variable, and removes the variable with the weakest predictive power from the model. It then repeats this process looking at the correlation of the remaining predictive variables, and removes the next weakest variable in the model.

Both forward and backwards SMR usually give the same results, but there are times when the different methods yields different predictive models. Under such situations, it is most common to pick the resultant model with the highest predictive power.

The central aim of the analysis was to investigate the strength of relationships between different western-based science assessments of stream health and those based on Māori cultural assessments. The western science measures were derived from four sources (Figure 2A), whereas the Māori cultural measures were derived from five different CSHM scores (Figure 2B).

A)




B)

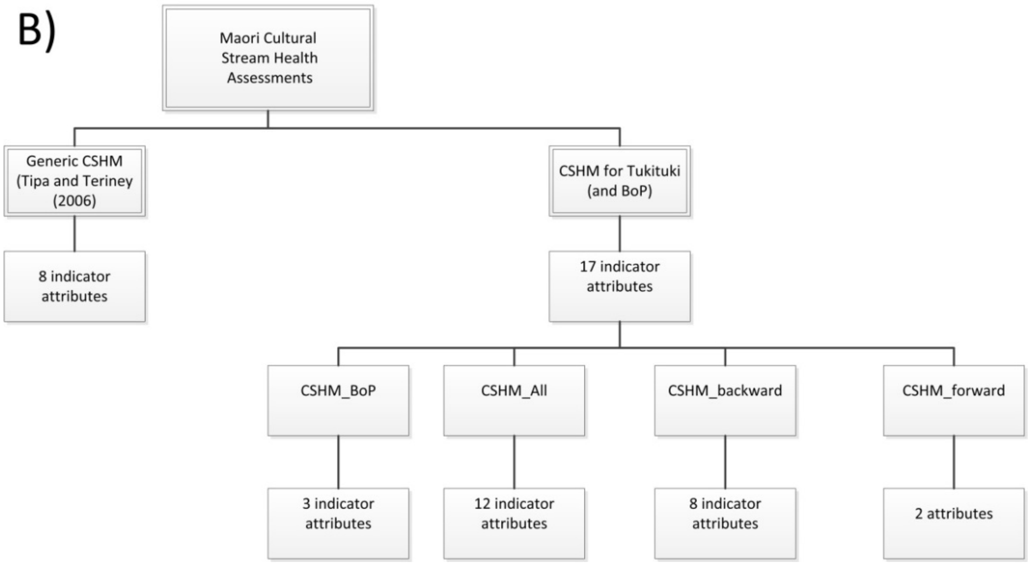



*Figure 2 Diagrammatic representation of the different ways of assessing stream health using A) western-based methods, and B) Māori cultural methods. In this study, western science methods were derived from either biological assessments of invertebrate communities, or physical assessments of land use or habitat. Māori cultural measures were based either on the generic CSHM methodology of Tipa and Tierney (2006), or on four measures derived from 17 indicator attributes.*

# Part 3: Results

## 3.1 Physical conditions

Most of the streams sampled were relatively small and shallow (Table 3), although a few wide streams were also sampled. Stream banks were undercut at most sites and overhanging vegetation was present at all sites. Calculated substrate indices were all relatively low (Table 3), reflecting the preponderance of fine substrates, often dominated by volcanic pumice at most sites. Hydraulic habitat diversity at most sites was low, with runs dominating the habitats at 28 sites. Calculated HABSCORES varied by a factor of almost three (Table 3), indicating large differences in measured environmental parameters between the different streams. This most likely reflected the large gradient in land use, with urban streams having low HABSCORES, while indigenous forest streams having high HABSCORES.

*Table 3 Summary statistics of habitat variables measured in each of the 37 streams.*

| Factor type | Factor | Minimum | Average | Maximum |
|---|---|---|---|---|
| Stream size | Width (m) | 0.72 | 4.86 | 21.6 |
| | Stream depth (m) | 0.09 | 0.52 | 1.02 |
| Banks | Bank undercuts (m) | 0 | 0.09 | 0.22 |
| | Overhanging vegetation (m) | 0.007 | 0.60 | 3.54 |
| Instream habitat | Substrate index | 0.11 | 0.285 | 0.562 |
| | Flow diversity | 1 | 1.6 | 4 |
| | Percentage riffles | 0 | 6.1 | 58.3 |
| | Percentage runs | 0 | 71.6 | 100 |
| | HABSCORE | 145 | 239 | 365 |
| Land use (% catchment cover) | Urban | 0 | 11.1 | 69.1 |
| | Pasture | 0 | 35.6 | 99.8 |
| | Exotic plantation | 0 | 19.8 | 96.5 |
| | Indigenous forest | 0 | 26.7 | 99.4 |

## 3.2 Ecological conditions

A total of 116 invertebrate taxa were collected during the survey. The fauna was numerically dominated by the common snail *Potamopyrgus*, three genera of mayflies (*Zephlebia*, *Austroclima* and *Coloburiscus*), chironomid midges, blackflies (*Austrosimulium*) *Oligochaete* worms, the stonefly *Zelandobius*, and the caddisfly *Triplectides*. Mayflies and stoneflies are regarded as being sensitive to pressures associated with land use changes such as loss of riparian vegetation, increased temperatures, and reduced water quality, while animals such as snails, midges and worms are tolerant of these conditions (Quinn et al 1997; Collier and Winterbourn 2000).

A wide range of MCI and QMCI scores were observed in the study (Table 4), emphasising the fact that a wide range of streams with different ecological condition were surveyed. Five streams were classed as in “Poor” condition based on their MCI scores, seven streams in “Fair” condition, 14 streams were in “Good” condition and ten in “Excellent” condition. Similarly, the number and percentage of EPT varied greatly, with some sites supporting none of these sensitive taxa, and others supporting a diverse community of these taxa, and at high densities (Table 4).

*Table 4 Summary statistics of selected biotic metrics to describe the invertebrate communities encountered in the 37 streams.*

| | MCI score | QMCI score | EPT | % EPT |
|---|---|---|---|---|
| **Minimum** | 54.7 | 1.6 | 0.0 | 0.0 |
| **Average** | 103.8 | 5.1 | 11.9 | 41.8 |
| **Maximum** | 137.5 | 7.9 | 30.0 | 87.2 |

Examination of calculated ordination scores showed a strong separation on Axis_1 according to dominant land use in each stream (Figure 3). Streams with low Axis_1 scores were dominated by taxa such as mayflies, caddisflies and stoneflies and had high biotic indices (Table 5), and came from catchments dominated by indigenous forest, with high habitat scores and a course substrate. The streams were also generally relatively large. In contrast, streams with high Axis_1 scores were from catchments dominated by pasture or urban land use. Biotic indices in these streams were low, as were the habitat scores. The streams were generally small, and dominated by fine substrate material.

These results suggest that the invertebrate community structure in the 37 streams changed in a predictable manner with changes in habitat, stream size and dominant land use. Sample spread along Axis_2 was not as great, and with the exception of one sample (the Puarenga River mouth), were mostly confined to a small range of scores (Figure 3).

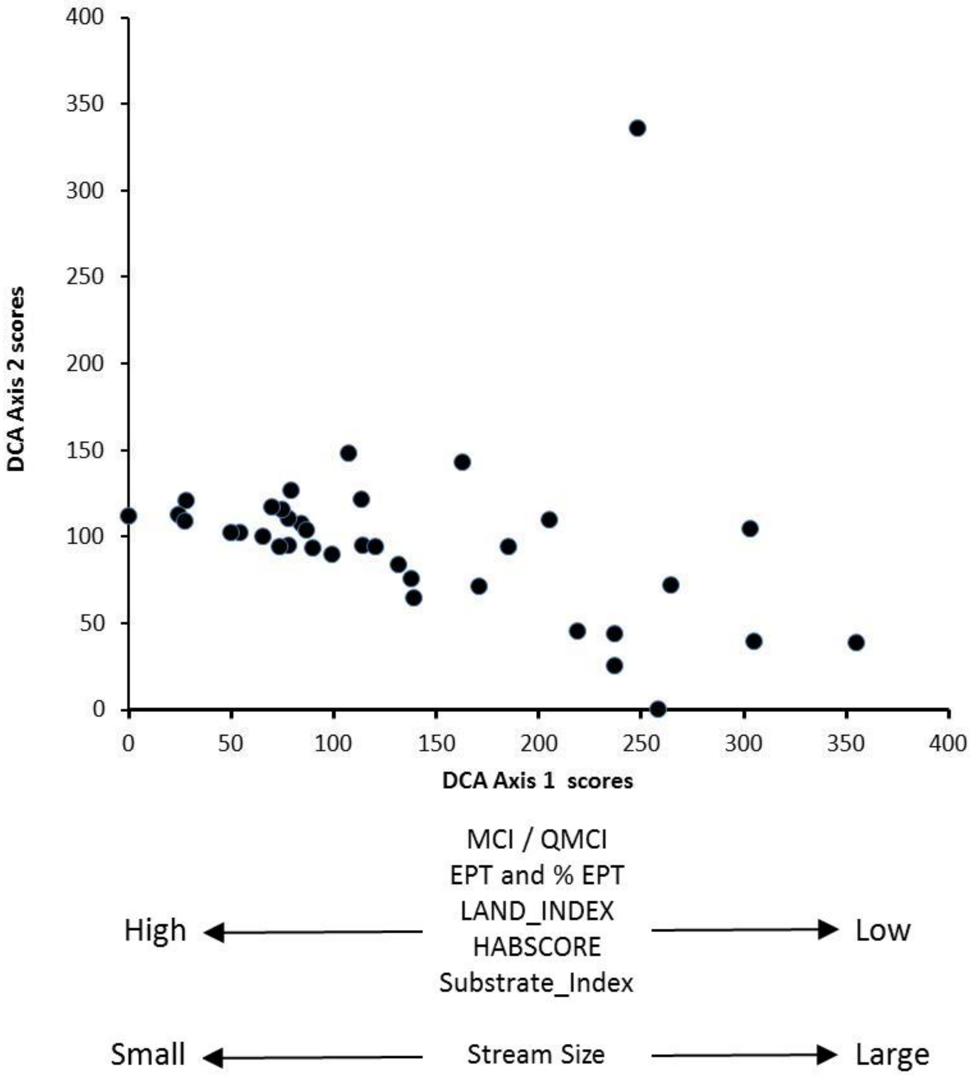



*Figure 3* *DCA ordination of invertebrate taxa collected at the 37 study sites throughout the Te Arawa/Rotorua Lakes region. The analysis showed that samples with low Axis_1 scores were generally from sites with high ecological metrics, and were from small streams with good habitat flowing through unmodified catchments. Streams with high Axis_1 scores had low ecological metrics, and were from larger streams with a generally poor habitat, flowing through modified catchments dominated by pasture or urban land use.*

*Table 5 Results of correlations between invertebrate abundance and the calculated DCA Axis_1 and Axis_2 scores.*

| | **Axis_1 scores** | | **Axis_2 scores** | |
|---|---|---|---|---|
| Invertebrate group | Negative correlations | Positive correlations | Negative correlations | Positive correlations |
| Mayflies | *Ameletopsis, Austroclima, Zephlebia, Coloburiscus, Deleatidium, Neozephlebia, Ichthybotus* | | | *Ichthybotus* |
| Caddisflies | *Orthopsyche, Hydrobiosis, Pycnocentria, Pycnocentrodes, Helicopsyche, Beraeoptera, Neurochorema, Zelolessica Hydrobiosella, Costachorema, Olinga,* Hydrophilidae*, Psilochorema* | | *Olinga, Zelolessica* | *Hydrobiosella, Paroxyethira* |
| Stoneflies | *Megaleptoperla, Acroperla, Zelandoperla, Austroperla, Zelandobius* | | | |
| Diptera | *Austrosimulium, Aphrophila, Eriopterini, Empididae, Mischoderus, Limonia* | *Chironomidae* | | *Hexatomini* |
| Coleoptera | Elmidae, Ptilodactylidae | *Lancetes* | | |
| Mollusca | | *Potamopyrgus, Gyraulus, Physella* | | Sphaeriidae, *Zelandotipula* |
| Others | *Archichauliodes,* Amphipoda*, Antipodochlora* | Hydrozoa, Collembola, Nematoda, Oligochaeta, Copepoda | | Polychaeta, Nemertea |

## 3.3 Cultural stream health measures

### 3.3.1 Comparison of different CSHM scores

Mahinga kai Indicators such as "*would you eat fish*", "*would you taste the water*" and "*life supporting capacity*" were all highly correlated with the holistic assessment of overall stream health, as was the indicator "*would you swim in the water*" (Table 6). This emphasises the fundamental importance of mahinga kai and recreational activities such as swimming to the overall cultural evaluation of stream health by tangata whenua. The only mahinga kai indicator not significantly correlated with the holistic assessment of overall stream health was that of "would you fish here". Given the mostly strong correlations of these mahinga kai indicators to overall stream health, they were not considered further in the development of a CSHM.

The remaining 12 indicator variables for the CSHM were then correlated to the assessment of overall stream health (Table 6). Significant correlations were observed for all variables, but the strength of the relationships was highly variable, ranging from a low of 0.204 (riverbank condition) to a high of 0.902 (water clarity).

*Table 6 Calculated correlation coefficients of the 17 individual indicator variables against the overall holistic assessment of stream health eight in each of the 37 sites.*

| Variable_type | Variable | | Correlation |
|---|---|---|---|
| CSHM | 1 | Catchment land use | 0.214 |
| CSHM | 2 | Riverbank condition | 0.204 |
| CSHM | 3 | Riparian vegetation | 0.318 |
| CSHM | 4 | Indigenous species | 0.331 |
| CSHM | 5 | Riverbed condition | 0.757 |
| CSHM | 6 | River channel modifications | 0.287 |
| CSHM | 7 | River use (takes and discharges) | 0.252 |
| CSHM | 8 | River flow (movement) | 0.385 |
| CSHM | 9 | Water quality | 0.807 |
| CSHM | 10 | Water clarity | 0.902 |
| CSHM | 11 | Use of riparian margins | 0.205 |
| CSHM | 12 | Variety of habitats | 0.525 |
| Mahinga kai | 13 | Would you taste the water? | 0.813 |
| Mahinga kai | 14 | How do you feel about fishing? | 0.486 |
| Mahinga kai | 15 | Would you eat fish? | 0.826 |
| Mahinga kai | 16 | Would you swim here? | 0.806 |
| Mahinga kai | 17 | Necessary food sources | 0.790 |

Forwards and backwards SMR was used to determine which of the 12 CSHM indicators were the most strongly related to the assessment of overall health. Both techniques identified the same three variables (bank condition, variety of habitats, and water clarity) as important variables in the resultant SMR models. These three variables were subsequently used to develop the CSHM_BoP.

Regression analysis showed that the CSHM_BoP has a much stronger predictive power to the assessment of overall stream health then did the generic CSHM (Table 7). The calculated $CSHM\_{All}$ (based on the average of all CSHM indicators) had the weakest predictive power to the assessment of overall stream health (Table 7), suggesting that using all the indicators to create a CSHM score did not truly reflect the overall holistic assessment of stream health.

The CSHM developed using forward SMR had the highest predictive power to the overall assessment of stream health (Table 7), and was based only on two indicators (water clarity and provision of necessary food sources). The CSHM developed using backward SMR also had a relatively high predictive power, and was based on eight indicator variables, three of which were related to mahinga kai.

*Table 7 List of indicator variables used for the calculation of the generic CSHM as outlined by (Tipa and Tierney 2006) and the indicator variables selected by SMR analysis on the data collected for the present study in the creation of four CSHM indices for potential use in the Bay of Plenty. Also shown is the strength of the resultant correlations of CSHM scores against the overall holistic assessment of stream health.*

| Variable | Generic CSHM | CSHM_BoP | CSHM_All | CSHM_forward | CSHM_backward |
|---|---|---|---|---|---|
| 1 Catchment land use | ✓ | | ✓ | | |
| 2 Riverbank condition | | ✓ | ✓ | | ✓ |
| 3 Riparian vegetation | ✓ | | ✓ | | ✓ |
| 4 Indigenous species | | | ✓ | | |
| 5 Use of riparian margins | ✓ | | ✓ | | |
| 6 Riverbed condition | ✓ | | ✓ | | |
| 7 Channel modifications | ✓ | | ✓ | | |
| 8 River flow | | | ✓ | | |
| 9 Water quality | ✓ | | ✓ | | ✓ |
| 10 Water clarity | ✓ | ✓ | ✓ | ✓ | |
| 11 River use (takes and discharges) | | | ✓ | | ✓ |
| 12 Variety of habitats | ✓ | ✓ | ✓ | | ✓ |
| 13 Safe tasting the water? | | | | | |
| 14 Safe swimming? | | | | | ✓ |
| 15 Feel about fishing? | | | | | ✓ |
| 16 Safe eating fish? | | | | | ✓ |
| 17 Necessary food sources | | | | ✓ | |
| Strength of model | 0.675 | 0.822 | 0.661 | 0.936 | 0.803 |

### 3.3.2 Relationships between CSHM scores and scientific assessments

Relationships between the five different CSHM scores and scientific assessments of stream health such as ecological metrics summarising the invertebrate community (MCI, QMCI, number and percentage of EPT taxa, and ordination scores) habitat conditions (HABSCORE) and the LAND_INDEX were assessed by regression analysis. Highly significant relationships were found between all the different CSHM scores and both ecological metrics and HABSCORE, and between all but the CSHM_forward and LAND_INDEX (Table 8).

The highest observed relationships were found between the generic CSHM and the western scientific methods, and the CSHM_All. This suggests that the generic CSHM as originally suggested by (Tipa and Tierney 2006) that assessed only eight indicators appears to work as well on the surveyed streams as well as a CSHM based on all the individual indicators.

These two indices were very highly correlated with each other (Figure 4), suggesting that the final choice of CSHM measure in further cultural health assessments within the Bay of Plenty may have little influence on the overall patterns found.

*Table 8* *Correlation coefficients ($r^2$ values) obtained from regression analysis of the different CSHM measures (including the generic CSHM and four CSHM indices developed for the Bay of Plenty) against different biological indices as used by western science, and against the calculated habitat score for each stream, and the LAND_INDEX score.*

| Variable | Generic CSHM | CSHM_BoP | $CSHM\_{All}$ | $CSHM\_{forward}$ | $CSHM\_{backward}$ |
|---|---|---|---|---|---|
| MCI | 0.425 | 0.289 | 0.406 | 0.257 | 0.365 |
| QMCI | 0.479 | 0.300 | 0.469 | 0.239 | 0.385 |
| Number of EPT taxa | 0.448 | 0.326 | 0.445 | 0.286 | 0.435 |
| % EPT | 0.368 | 0.276 | 0.361 | 0.201 | 0.328 |
| Axis_1 | 0.509 | 0.338 | 0.480 | 0.311 | 0.431 |
| Axis_2 | | | | | |
| HABSCORE | 0.381 | 0.243 | 0.394 | 0.161 | 0.264 |
| LAND_INDEX | 0.179 | 0.116 | 0.206 | n/s | 0.113 |
| Average $r^2$ | 0.398 | 0.269 | 0.394 | 0.207 | 0.331 |

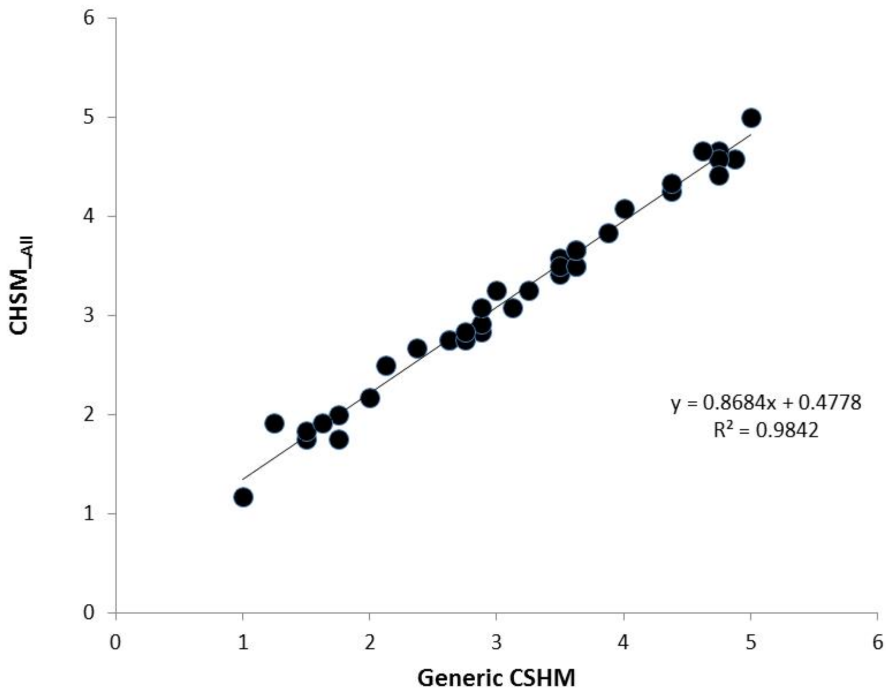



*Figure 4* *Regression between the calculated generic CSHM based on the eight indicators as identified by Tipa and Tierney (2006) and the CSHM developed based on the average of all 17 indicators collected in the study ($CSHM\_{All}$).*

# Part 4: Discussion

## 4.1 Relationships between western science and Māori cultural health assessments

Results of our analysis clearly showed strong relationships between the CSHM scores that were derived as part of cultural health assessments of each stream and assessments of stream health based on western scientific methods. Although Tipa and Tierney (2006) developed a generic CSHM for nationwide use, this is the first time that such comparisons have been made within the Bay of Plenty. We thus took a conservative approach and calculated both their generic CSHM, as well as four new versions of the CSHM based on the Bay of Plenty data. Although we found strong relationships between all of our different versions of the CSHM and western scientific measures of stream health, the strongest relationships were for the generic CSHM and the $CSHM\_{All}$ that was based on the average of all 17 indicators that were assessed at each site. The strong relationships between these two CSHM scores and western science scores of ecological metrics (and in particular to the Axis_1 ordination scores that summarises major changes in the invertebrate community composition) is particularly striking given the fact that none of the CSHM indicators dealt specifically with aquatic invertebrates.

Examination of the indicators used in the CSHM shows that many of these influence invertebrate communities. For example, hydraulic variability within a stream has been shown to have profound influences on biological processes (Carling, 1992; Collier et al.1995; Davis and Growns, 1991; Statzner and Higler, 1986), and this is captured by indicators such as “river flow”, and "a variety of habitats". Assessments of "riverbed condition" as part of the CSHM assess the degree to which the sediment is covered by mud or sand, and the effects of sedimentation on stream health have also been well-documented by western science (Broekhuizen et al. 2001; Suren, 2005; Waters, 1995).

Finally, there have been many scientific articles written on the effects of riparian vegetation on streams, highlighting its importance in providing food in terms of litter inputs (Cummins, 1974; Moser, 1991; Scarsbrook et al. 2001), modifying temperature regimes by providing shade (Rutherford et al. 1997), taking up nutrients and stabilising banks (Quinn et al.2001), and actively controlling channel morphology (Davies-Colley, 1997; Sedell et al. 1988; Zimmerman et al. 1967). All of these functions are encapsulated by assessments of “*riparian vegetation*”, “*indigenous species*”, and “*use of the riparian margin*” as part of the CSHM assessments.

Many of the CSHM indicators are also routinely assessed as part of instream habitat assessments (Barbour and Stribling, 1994; Harding et al.2009; Plafkin et al.1989), again emphasising commonalities between the two approaches. This suggests that despite their wildly different origins and philosophical backgrounds, cultural health indicators using the CSHM may in fact have more similarities to western science assessments then we possibly give credit to. This statement is not, however, aimed at minimising the important differences between the two approaches.

Western science assessments of stream health are by nature highly reductionist and focused on measuring scientific indicators which are objective and quantifiable, and used in testing specific hypotheses (Harmsworth et al 2011). This differs fundamentally from the more holistic, qualitative and observational approach of cultural indicators, which base their knowledge on a huge degree of collected in-depth experience built up over generations by communities who have close associations with rivers and what they can provide in terms of mahinga kai, and other values.

## 4.2 The Puarenga Catchment: contrasts between scientific and cultural assessments

Use of the CSHM to assess stream health from a Māori cultural perspective may provide greater insights into the overall condition of streams in the Puarenga Catchment than could be obtained if purely western science measures were used.

For instance, despite the relatively strong correlations between CSHM scores and ecological metrics when all 37 sites were assessed, no such relationships were observed between the two metrics for sites in the Puarenga Catchment (Figure 5). This means that the two methods of assessing stream health in this catchment were most likely assessing non-related components. Two sites (the Kauaka Stream and a site below the confluence of the Tureporepo, Kauaka and Puarenga Streams) showed higher MCI scores (both sites scored high in the "Good" category) than were predicted given their low CSHM scores (Figure 5).

Examination of the individual indicator components of the CSHM showed that these sites scored lowly for "*use of the river banks*", "*water quality*" and "*water clarity*", "*bed condition*", and "*catchment land use*". They also scored the lowest ratings for indicators such as "*safe to eat fish?*", "*would you fish here?*", "*would you swim here?*", and "*would you taste the water here?*". Their MCI rating score was, however, assessed as being in the "Good" category of the four water quality classes of Stark and Maxted (2007b).

During each individual CHI assessment, qualitative comments are made on each stream. Examination of these comments revealed statements such as (for the Kauaka Stream) "*the catchment is well-documented as a receiving body for pollutants*", and that there are "*known discharges upstream, and stormwater run-off*". This site receives diffuse run-off from the Rotorua District Council's land treatment system whereby treated sewerage is spray-irrigated into the pine forests. Thus, despite the fact that the MCI score at this site is relatively high, from a Māori cultural perspective it is rated very low due to the fact that it is the receiving environment from the land disposal system.

Tipa and Tierney (2006) make reference to this in terms of findings of the Waitangi Tribunal. Here, they note that the Waitangi Tribunal has stated that the discharge of effluent or human waste is an affront to traditional Māori concepts, and that it is irrelevant to argue that it has been treated to a high scientifically defined standard before it has been discharged into a river. This concept is clearly apparent in this situation whereby the Kauaka Stream scored very low from a CHSM perspective, but high from a western-science perspective.

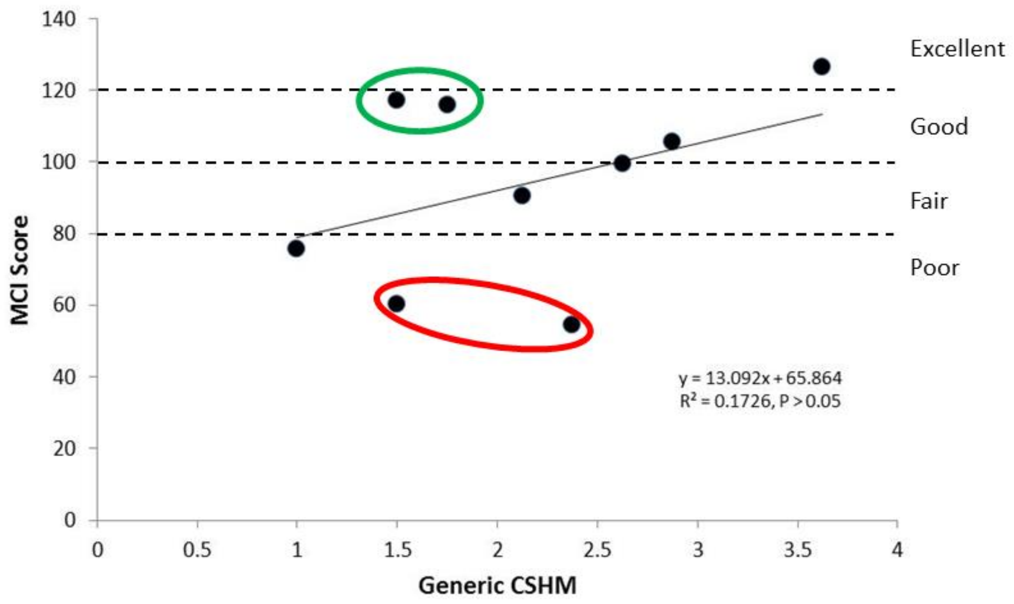



*Figure 5 Regression between the calculated generic CSHM and calculated MCI scores from nine sites in the Puarenga Catchment. Note how two sites (circled in green) had much higher MCI scores than predicted CSHM scores, while two other sites (circled in red) had much lower MCI scores. Note also that the fitted regression line is not significant.*

The site below the confluence of the Tureporepo, Kauaka and Puarenga Streams also had a relatively high MCI Score, but low CSHM score. The CHI assessments record this as being "*the merging of waters which causes poor water quality*". This highlights the Māori holistic concept of ki uta ki tai, whereby conditions in a catchment are considered in their entirety. Although western science acknowledges the concept of longitudinal connectivity along rivers (e.g., Harding et al.1999; Vannote et al.1980), it does this purely from a reductionist point of view in terms discrete elements such as the distribution of biota (Cowie, 1983), or changes in energy inputs (Biggs and Lowe, 1994; Bott et al.1985; Young and Huryn, 1996).

Furthermore, although western science and the indicators it relies on suggests that “stream health” can recover at distances below point source discharges (Biggs, 1989; Winterbourn et al.1971), it does not recognise the fact that the mauri of a river could be significantly degraded as a result a point source discharges of sewerage. Everything below this point source discharge would be viewed with caution by iwi despite the fact that, from an ecological point of view, any adverse effects could be limited to a relatively short section of river.

The concept of ki uta ki tai and the importance of maintaining mauri poses significant challenges to policymakers in setting acceptable limits to discharges in a resource consenting situation where thought processes within the regulatory authority are dominated largely by western scientific thinking. In particular, consenting officers and policymakers have reference to a number of clearly defined technical documents that outline acceptable levels of contaminants such as heavy metals, bacteria, and nutrients for the maintenance of aquatic ecosystem, and human health (e.g., ANZECC, 2000), NPS for freshwater NOF Guidelines (MfE, 2013), MfE periphyton and nutrient guidelines (Biggs, 2000), MfE Cyanobacterial Guidelines (Wood et al. 2009). Many of these guidelines have set upper limits for the protection of either aquatic ecosystem or human health, based on concepts such as LOEC (lowest observable effect concentration), and $LC_{50}$s. Implicit in these concepts is the fact that the more diluted a substance becomes, the less impact it will have.

This is totally counter to traditional Māori way of thinking. For example, Kemeys (2014) wrote an addendum to the cultural impact assessment prepared by Staite and Lee (2013) for a new application by the Rotorua District Council to increase the nutrient discharge loading to their land treatment system. Kemeys noted that "*the wider environment and public is exposed to the contamination as it flows from the Puarenga, to Lake Rotorua, Ohau channel, Kaituna River and Maketu coastline*".

Contrast this to the western science perspective. Here, any contaminants (with the exception of nutrients) flowing from the Puarenga Stream (mean flow = 1.75 $m^3/s$) into Lake Rotorua (volume = c. 800 000 $m^3$), and flowing from there through the Ohau Channel and down the Kaituna River (mean discharge = 39.5 $m^3/s$) into the estuary would simply be diluted to levels well below detection. Any excess nutrients entering these systems from the Puarenga Stream would unlikely have any demonstrable ecological effects, and would also be minor when compared with nutrients entering the systems from land use activities in the lower parts of the catchment.

Two other sites in the Puarenga Stream were shown to have lower than expected MCI scores based on their generic CSHM score. These sites were from areas below the natural geothermal inputs into the Puarenga Stream. These natural geothermal inputs were likely to have greatly affected the nature of the invertebrate communities, and lowered the resultant MCI scores.

## 4.3 Use of the CHI to set limits and direct policy

Following the development of their generic CSHM, Tipa and Tierney (2006) identified a number of unresolved issues concerning the implementation of the CHI (of which the CSHM is but one component). Some of the issues included whether regional councils would recognise these Māori values, and if adopted, would they fully appreciate their relevance and give them appropriate weighting along with "scientific" values.

Our analysis has shown a high degree of concordance between the CSHM and a number of biotic metrics used by western science. As such, it seems irreconcilable that indicators such as the CSHM would not be given similar weighting. However, despite the undeniable value of using freshwater invertebrates as biological indicators of stream health (Boothroyd and Stark 2000; Stark et al. 2001), and the widespread (almost universal) use of biological monitoring of streams by councils throughout New Zealand, even well-established biotic metrics such as the MCI are generally absent from policies and plans. The comments of Tipa and Tierney therefore can equally apply to western science metrics!

Environmental management within New Zealand is enshrined under the RMA, which holds as its cornerstone the sustainable management of resources. One of the recurring themes in many of the sections of the RMA is that of the need to protect or maintain the "*life supporting capacity*" of a water body. However, there is no broad consensus as to what "*life supporting capacity*" actually means. Lack of such guidance may be one reason why numeric metrics such as the MCI are not widely used in council policy and plans.

Under the RMA, regional councils are responsible for setting objectives for the management of freshwaters in their region. A means to this are Regional Plans that have a number of policies, methods and rules in them to ensure that development is not counter to the purpose of the RMA. The overall purpose of the Bay of Plenty Regional Water and Land Plan (RWLP) is to achieve a number of specific aims, including the promotion of sustainable and integrated management of water resources, maintaining or improving environmental quality in the region, sustaining the life supporting capacity of water and ecosystems, and maintaining or enhancing the ecological, and Māori cultural values of water. Under section 30 of the RMA, the BOPRC also has the responsibility to control use and development activities for the purposes of maintaining or enhancing water quality, maintaining and enhancing aquatic ecosystems, and maintaining water quantity.

Chapter 3 of the RWLP recognises that land use and management practices that are inappropriate to the specific characteristics of the site may cause adverse effects on the environment (Issue 10), and that water quality in some streams, rivers, lakes in the region can be adversely affected as a result of use and development activities (Issue 12). Although there is a recognition that adverse effects on water quality can include changes to instream biota composition and abundance to a more pollution tolerant species, the RWLP makes no attempt at defining specific numeric guidelines for biotic metrics such as the MCI, despite the strong implication that MCI scores can decrease as a result of changes to water quality. Instead, the RWLP relies on overarching objectives stating that water quality in rivers and streams is maintained or improved to meet one of eight water quality classifications established by the council. However, these eight water quality classifications contain only narrative statements about the need to "*maintain healthy and diverse aquatic ecosystems*". Moreover, they apply mainly only to point discharges to waterways as there is little control over diffuse discharges from intensive land use in the RWLP.

A disconnect therefore exists therefore between our ability to set specific numeric guidelines for biological communities (and therefore by extension overall stream health) and the very policies, methods and rules set by the RWLP to ensure the sustainable management of water resources. Lack of such numerical guidelines for biological communities contrasts sharply with the somewhat more quantifiable targets for many water quality parameters set in the regional rules. For example, discharges are not meant to result in a conspicuous change in colour or visual clarity (e.g., Rule 7 and 22), or contain more than a specified amount of suspended sediment, or contain substances that are toxic to aquatic ecosystems (e.g., Rule 30). Furthermore, specific rules concerning the discharge of nutrients into the Rotorua lakes have been developed (e.g. Rule 11), and specific measurable targets have been set for the Rotorua Lakes based on the Trophic Lake Index (a composite of nitrogen, phosphorus, chlorophyll a and water clarity).

Numeric targets for invertebrate communities (such as the MCI) generally do not exist in council plans throughout New Zealand, although Horizons Regional Council in their One Plan initially proposed that QMCI scores not decrease by more than 20% upstream and downstream of discharges to water. This proposal has now been modified to state "*the QMCI score shall not show a statistically different reduction upstream and downstream of discharges to waterways*". However, this rule applies to point source discharges only, which are arguably much easier to manage than problems associated with diffuse discharges, and the effects of habitat change as a result of land use intensification.

To our knowledge, no other councils have attempted to set numerical values for biotic indices that allow an assessment to be made whether indeed the "*life supporting capacity*" of a stream is still being maintained, or that "*healthy and diverse aquatic ecosystems"* are in fact being maintained. If widespread and well-documented biotic indices have not been incorporated into policies and plans, then the concerns of Tipa and Tierney are as relevant for western science metrics as they are for cultural metrics.

Environmental monitoring using freshwater invertebrates to assess stream health will only tell the current state of a particular water body. However, predictive models have been developed (Clapcott et al. 2011; Leathwick et al. 2007) that show what the invertebrate communities (as expressed by the MCI) would have been in the absence of land use changes. These predictive models are important in that they consider only natural drivers of invertebrate community composition such as climate, geology, source of flow, and land use (prior to the human change) and recognise that not all streams would support similar communities. Thus, for example, soft-bottomed lowland streams would always have a lower MCI scores than gravel-bed foothill streams.

Based on these predictive MCI scores, it is possible to determine the shift in ecological health due to land use intensification. It may be possible to develop guidelines for the observed MCI scores at a site based on a maximum allowable difference to that predicted in the absence of human disturbance. As with the Horizons One Plan, it would also be a relatively simple matter to write rules into resource consent conditions stating that biotic metrics such as the MCI should not be reduced by more than a certain percentage below a point source discharge. Finally, under the new NPS for freshwater, there is an overall goal to maintain or improve water quality in regions. This means therefore that default numeric limits for metrics such as the MCI could be used to ensure that these do not decline further over time.

If such numeric targets for the MCI can be developed, then there is no reason why similar targets for the CHI and in particular the CSHM component could not be developed as well. In this case, overall policies could ensure that there would be no overall decline in Māori cultural values over time. An additional advantage of the CHI approach is that it relies heavily on traditional knowledge.

Tipa and Tierney (2006) also highlight the value of whakapapa in the assessment of a CHI, and emphasise that it uses traditional knowledge and recognise interactions between different parts of an ecosystem, and the mahinga kai species present. This means that both a contemporary CHI and a historic CHI could be produced for a particular site. As with the MCI approach, it should be possible to set rules and impose consent conditions to ensure that Māori cultural values and the mauri of a particular stream (as assessed by a CHI) are not degraded by more than a specified amount (or not at all).

If this approach were taken, it would also fulfil many of the objectives, policies and methods in Chapter 2 of the current RWLP. This chapter specifically deals with kaitiakitanga, and highlights that kaitiakitanga includes the principles of guardianship, care and wise management, as well is the protection, enhancement and restoration of mauri.

A number of issues are highlighted in this chapter, including:

- Issue 3: the role of tangata whenua as kaitiaki of water is given token regard, or not being recognised at all;
- Issue 4: tangata whenua feel that their concerns about water are not fully addressed during resources management decisions;
- Issue 8: the mauri of water has been degraded, and needs to be protected and restored.

Implementation of the CHI is likely to go a long way in addressing these issues. Moreover, under Objective 4 of the RWLP, the use of a CHI would allow the water concerns of tangata whenua to be taken into account and addressed as part of resource management processes, especially if consent conditions were written to ensure that a CHI is not reduced below a specific activity. Although this would be no different to a similar condition requiring no reduction in MCI, it is not without challenges, especially given the example of differences in the MCI and CHI assessments of streams in the Puarenga Catchment.

# Part 5: Conclusion

This study examined relationships between western science-based ecological methods at assessing stream health and traditional Māori cultural health assessments. We utilised the generic CSHM component of the CHI methodology as outlined by Tipa and Tierney (2006) that assessed a stream's cultural condition based on eight indicators. Strong relationships were found between the generic CSHM and a number of different biological indices used to describe the overall ecological condition of a stream. We also created a CSHM specific to the Bay of Plenty (called $CSHM\_{All}$) the utilised all 17 indicators as originally suggested by Tipa and Tierney (2006), as we recognised the fact that the original indicators of the generic CSHM may have omitted key cultural values of iwi in the Rotorua and Te Arawa/Rotorua Lakes region.

We found that the $CSHM\_{All}$ measure also displayed strong relationships to biological metrics, and to the generic CSHM. That such strong relationships exist between western science and Māori cultural health measures suggests that the latter could be used in helping formulate policies and plans in the RWLP, and in setting limits as part of consent conditions in a similar way that western science metrics should also be used.

Comparison of western science-based biological metrics collected from sites in the Puarenga Catchment to CSHM scores revealed intriguing and highly relevant differences between the two methods. Most notable is the fact that many of the metrics used by western science have an implicit assumption in them that ecosystems can recover from the adverse effects of contaminants as the concentration of these contaminants is diluted. This is at odds with many Māori concepts including the maintenance of the overall mauri of the stream, and that of ki uta ki tai. Such differences need to be recognised by the Council especially in terms of processing resource consent applications and imposing consent conditions.

The study was based only on 37 sites throughout the Rotorua and Te Arawa/Rotorua Lakes region. As such it is too soon to make a final recommendation as to whether the generic CSHM as espoused by Tipa and Tierney (2006) should be used for further work throughout the Bay of Plenty region. Instead, we recommend that any future CHI work collect at least the same data examining the 17 indicators for the calculation of the CSHM as done in the study. We also recommend that any future work also examine both the present day mahinga kai values of the stream, as well as traditional values. This comparison is the same as component 2 of the CHI index, and would provide valuable information at the potential loss of mahinga kai species from a particular site.

There is a strong need for a CHI survey to be conducted of waterways throughout the Rangitāiki River Catchment as part of work to be done for the Rangitāiki River Forum. Any such, work would need to be cognisant of potential differences between iwi and hapū, and it is recommended that relevant protocols be followed and potential indicators for a CSHM be discussed at any hui. Such protocols for use of the CHI by other iwi are outlined in Tipa and Tierney (2003). It is hoped that this work, and the potential future survey work to be conducted for the Rangitāiki River Forum will have a number of tangible benefits including:

- An increased awareness as to the importance of maintaining and enhancing the mauri of waterways throughout the region;
- The use of the CHI, and in particular the CSHM to assign a numerical value to the holistic concept of mauri;
- The ability for the Council to address key issues identified in the RWLP, including Issue 3 (that the role of tangata whenua as kaitiaki of water is given token regard, or not being recognised at all), and Issue 4 (that tangata whenua feel that their concerns about water are not fully been addressed during resource management decisions) as identified in Chapter 2.

Finally, consideration should be given into the possibility of including some form of CHI assessments as part of the Council's Natural Environment Regional Monitoring Network (NERMN) that allows the Council to monitor the state of, and trends of the region's streams and lakes. Results from the NERMN programme are meant to assist in determining whether the objectives of regional plans and strategies are being achieved. The inclusion of CHI assessments in this program would greatly help council achieve the aims and objectives of kaitiakitanga.

Such assessments would obviously need to be done by tangata whenua, and may initially involve considerable liaison between different iwi and hapū, but it is felt that any benefits gained from this would prove invaluable for the Regional Council in its role of sustainable management of freshwaters throughout the region.

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# Appendices

# Appendix 1 – List of the different indicator elements used in the current study to assess the Māori cultural stream health measure

| No. | Indicator | 1 Unhealthy | 2 | 3 | 4 | 5 Healthy |
|---|---|---|---|---|---|---|
| 1 | Catchment land use | Land heavily modified wetlands, marshes lost | | Farmland | | Appears unmodified |
| 2 | Riverbank condition | Banks eroding | | Some erosion | | Banks appear stable |
| 3 | Riparian vegetation - banks and margins (100 m either side) | Little or no vegetation | | | | Complete cover of vegetation |
| 4 | Indigenous (native) species - margins and upstream catchment | Only exotic species visible | | Exotic/native | | All indigenous (native) species visible |
| 5 | Riverbed condition (sediment) | Covered by mud/sand, slime, weed | | Sand/algae | | Clear of mud/sand/sediment/weed |
| 6 | Channel modifications | Evidence of modification | | | | Changes to river channel |
| 7 | Use of the river (takes/discharges) | 1 Major takes/discharges | | | | No takes or discharges |
| 8 | River flow | Cannot see movement | | | | Broken/white water |
| 9 | Water quality | Appears polluted e.g. foams, oils, slime, weeds etc. | | | | No pollution evident |
| 10 | Water clarity | Water badly discoloured | | | | Water is clear |
| 11 | Use of the riparian margin | Margins heavily modified | | Riparian strips | | Margins unmodified |
| 12 | A variety of habitats | 1 No variety in habitat flow and habitat uniform | | Smooth to ruffled | | A range of habitats present channel winding, flows from smooth to broken white water |
| 13 | How safe would you feel tasting the water at this site? | 1 Completely unsafe | | Questionable | | Completely safe |
| 14 | Would you fish at this site? | I would not fish here | | | | This is a great place to fish |

| No. | Indicator | 1 Unhealthy | 2 | 3 | 4 | 5 Healthy |
|---|---|---|---|---|---|---|
| 15 | How safe would you feel eating fish caught at this site? | Completely unsafe | | | | Completely safe |
| 16 | How safe would you feel swimming at this site? | Completely unsafe | | | | Completely safe |
| 17 | When you look at this site, do you see the necessary food sources to support the life in and around the river? | No food sources present | | | | Abundant food sources |
| 18 | How would you describe the overall health of the river at this site? | Very unhealthy | | | | Very healthy |
| ACCESS | Do you consider access to this site is sufficient to harvest mahinga kai? | Not able to gather at this site | | | | Able to gather - no restrictions |
| | Would you return to this site in the future? | No | | Monitor only | | Yes |