Waterways
Centre for Freshwater Management

An Assessment of the Value and Feasibility of Mahinga Kai at UC

Summary Scholarship Report

WCFM Report 2013-005

UC SUSTAINABILITY

UC
UNIVERSITY OF CANTERBURY
Te Whare Wānanga o Waitaha
CHRISTCHURCH NEW ZEALAND

REPORT: WCFM Report 2013-005

TITLE: **An Assessment of the Value and Feasibility of Mahinga Kai at UC** (including assessment of potential urban contaminant effects on mahinga kai development)

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EXECUTIVE SUMMARY

This project looked at the feasibility of producing food in a way that strengthens mana whenua as kaitiaki at the University of Canterbury (UC). It focussed on the potential for mahinga kai development in Wai-utuutu Stream, which is part of the Ōtākaro River and receives stormwaters and other wastes from the university campus environment. This project assessed the information required to determine cultural and scientific factors associated with waterway health.

The methodology involved review of both Mātauranga Māori and scientific analysis literature that focussed on stormwater input, ecological indicators, and cultural health indicators, and the relationship between contaminants and various plant and animal species. The waterway's history in Christchurch, Mana Whenua history of mahinga kai, cultural values associated with mahinga kai and waterways, as well as contamination issues associated with heavy metals were reviewed.

The feasibility of traditional mahinga kai in the Wai-utuutu Stream is not supported by this study. However, there is an opportunity to assess the role of mahinga kai as biological engineers to effectively remove metals from the waterway and along riparian zones. This supports past research recommendations to remediate Wai-utuutu Stream and minimise the ecological effects of stormwater inflow.

Land-based mahinga kai is instead recommended to fulfil the role of tikanga associated with marae and mahinga kai. This supports the UC Campus Master Plan to utilise existing space and enhance places of social and cultural hubs.

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Ngā mihi nui

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GLOSSARY

Kupu Hou – Māori terminology

Atua	god, ancestor with continuing influence but, more correctly, ancestors whose mana is extant, usually in a specific domain
Hapū	sub-tribe
Hui	gathering, meeting, assembly
Iwi	tribe, extended kinship group
Kaitiaki, Tangata tiaki	guardian
Kaitiakitanga	guardianship
Mana	prestige, authority, control, influence
Manaakitanga	to care for, kindness
Tangata whenua	people of the land, local people
Tāonga	treasure, something highly prized
Tapu	sacred, prohibited, area under a supernatural condition
Tikanga	correct procedure, custom,
Tohunga	skilled person, expert

hapū	sub-tribe, extended family
mahi kai	food harvesting/preparation
mahinga kai	place where food is obtained
mana whenua	the right to harvest, or make decisions over, resources in the area
Mana Whenua	the people who hold the mana whenua
mātauranga Māori	knowledge and values
mauri	essence, life principle/ conduit by which the mana of ancestors may draw near
rāhui	to restrict access
rangatira	person of chiefly rank
rangatiratanga	expression of ones chieftainship
takiwā	district
tangata whenua	people of the land/the people belonging to a locality
tikanga	correct way, rule
tohunga/tohuka	expert, especially in ritual
whakapapa	genealogy
whakataukī	proverbs

"Food is not just a resource for sustenance…
Food needs to be understood as a wider cultural concept
that interweaves complex Indigenous cultural and environmental relations,
relations that Adelson (2000) constructs as the opportunity to experience 'being alive well'"
(Panelli and Tipa, 2009)

1 INTRODUCTION

1.1 Background

Water is an important resource, regarded as a fundamental taonga[1] by Māori. Māori have cultural, historical, and spiritual links with many of the country's springs, wetlands, rivers, hot pools, and lakes. Waterways were considered by Tīpuna as the arteries of Papatūānuku[2], in that each waterway is as important and vital as the other, and that all are interconnected (MfE, 2005b). The health of water bodies is important for customary and social uses, and especially for mahinga kai[3]. The 'direct' food gathering involved with mahinga kai requires a pristine environment (Te Rūnanga o Ngāi Tahu, 2004). Many cultural customs are sustained through mahinga kai, such as in the transgenerational transfer of knowledge and understanding of cultural wellbeing (Te Rūnanga o Ngāi Tahu, 2004).

The Wai-utuutu/Okeover, Ilam, and Avon Streams are tributaries of the Ōtākaro/Avon River that run through the University of Canterbury campus, in Christchurch. The streams arise as groundwater springs from shallow aquifers recharged by rain in the Southern Alps and have high water quality (Hewson *et al*., 2006). Together these three waterways represent a distinct sub-catchment, with the Ōtākaro continuing to Te Ihutai/Avon-Heathcote Estuary.

The water quality and indigenous biota of both major rivers, the Ōtākaro and Ōpāwa/Heathcote Rivers, have been affected by historical and continued urban run-off of residential and industrial areas (Tau *et al*., 1990; Pauling *et al*., 2007). Over time, building developments in the vicinity of the Campus Waterways have degraded the Wai-utuutu Stream. Water flows have decreased as the water table has dropped and this in turn has increased the amount of sediment on the stream bed (Environmental Canterbury, 2010). The stormwater inputs may have impacted previous indigenous biota, including mahinga kai species. This project aims to assess the feasibility of mahinga kai according to Māori cultural values for the environment in reference to the University Campus waterway. This study attempts to review the current state of the Wai-utuutu Stream waterway the ecological population health and the cultural values in reference to mahinga kai.

1.2 Current Study

This project fulfils part of the Sustainability summer studentship to look at the feasibility of mahinga kai at the University of Canterbury (UC) in a way that strengthens Mana Whenua as kaitiaki. The waterway of focus is the Wai-utuutu Stream, a tributary of the Ōtākaro River,

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[1] Tāonga: Gift, treasure, award,
[2] Papatūānuku: Mother Earth,
[3]The general term mahika kai to refer to 'places at which food (and other commodities) were extracted or produced (Anderson, 1998:111)'

which runs through UC campus. This river runs through the urban environment, where there are many inputs of anthropogenic pressures.

The Wai-utuutu Stream has a history of restoration and research. This report aims to assess the relationship between the current research findings to that of cultural values, as this has not been researched. Mahinga kai is assessed according to the changes to the Wai-utuutu ecosystem and associated species over time, the cultural values of environmental health, and the effect of stormwater associated-contaminant input to mahinga kai.

1.3 Study Objectives

Specifically, this report reviews the contaminants information, the cultural values, the Campus Master Plan, and the local waterways management framework in terms of mahinga kai. The information is collected at a local, national, and international level where relevant. The study questions to achieve these objectives are:

1. How can the university campus produce food in a way that acknowledges and strengthens Mana Whenua as kaitiaki?
2. What are the opportunities for doing this at the University of Canterbury?
3. What, if anything, has already been achieved in this vein?

1.4 Contextural Literature

1.4.1 On Mana Whenua and Mahinga Kai

Ngāti Waitaha who settled and occupied near the Estuary first, were followed in the 1500s by Ngāti Mamoe, and then around one hundred years later by Ngāi Tahu (Tau *et al*., 1990). The Ngāi Tahu population increased during the 1930s and maintained a number of settlements along these rivers, as well as other sites across Canterbury (Tau *et al*., 1990). The Christchurch area was utilised extensively as places of mahinga kai (Tau *et al*., 1990). Mahinga kai, with the literal meaning 'working the food', refers to the sustainable gathering of food and resources, the places where they are gathered and the practices used in doing so (Te Rūnanga o Ngāi Tahu, 2004). Along with whakapapa (genealogy), mahinga kai, is the main axle upon which Ngāi Tahu identity with the natural environment revolves (Te Rūnanga o Ngāi Tahu, 2004).

The Ōtākaro and Ōpāwa Rivers[4] were highly regarded mahinga kai in the Christchurch area of food-rich wetlands (Tau *et al*., 1990). These lands that surrounded the rivers were divided into wakawaka (boundaries) and controlled by the rangatira of certain hapū and whānau (Tau *et al*., 1990). Te Ihutai Estuary was also important as part of a larger fishery used by Ngāi Tahu (Tau *et al*., 1990).

[4] Properly known as Ōtākaroro and Ōpāwaho, for Avon and Heathcote Rivers respectively (Tau *et al*., 1990)

Traditionally, the Ōtākaro and Ōpāwa rivers supported various mahinga kai species including tuna (shortfin eels, *Anguilla australis*, and longfin eels, *A.dieffenbachia*), kanakana (lamprey, *Geotria australis*), tuere (hagfish, *Eptatretus cirrhatus*), and pātiki (flounder, *Rhombosolea retiaria*), as well as waikōura (freshwater crayfish of the eastern side of the South Island, *Paranephrops zealandicus*), and waikākahi (freshwater mussels, *Echyridella menziesi*) caught from the banks of the river (Tau *et al*., 1990). Birds that were associated with the waterways were also caught such as pūtangitangi/pūtakitaki (paradise duck, *Tadorna variegata*), and parera (grey duck, *Anas superciliosa*) were caught from the swamps and mouth of Ōtākaro (Tau *et al*., 1990). The mouth of Ōtākaro was a permanent mahinga kai that included inaka/inanga (adult whitebait, *Galaxias maculatus*), kokopu (native trout, *Galaxias* spp.), as well as a place where kumara (*Ipomoea batatas)* and aruhe (bracken/fernroot, *Pteridium aquilinum var. esculentum*) were cultivated in the sandy soils (Tau *et al*., 1990). Te Ihutai was also known to hold tuna, kanakana, inanga, pātiki and pipi (*Paphies australis*).

There are many sites[5] that are no longer mahinga kai after being taken by colonial processes (Tau *et al*., 1990). Mana Whenua attempted to have mahinga kai reserves in place for traditionally significant sites, but were unsuccessful. The Ihutai Māori Reserve was taken in 1956 under the Public Works Act, and then Ihutai received the output as part of the Christchurch sewage works development and subsequently discharge of sewage (Tau *et al*., 1990).

1.4.2. On cultural values: Mauri, Mana, and Manaaki

The terminology mauri, mana, manaaki, kaitiakitanga, and rangatiratanga are values that are best described together, as they have an interwoven existence within tikanga Māori (See glossary also). Mana Whenua are usually those who belong to one hapū that hold whakapapa and govern a specific area. The mana of a people, is demonstrated by the health of their environment, exemplified when hosting another hapū or iwi through manaakitanga by providing a place to stay and natural local sourced sustenance and taonga species to share. Rangatiratanga in this case, is the ability of Mana Whenua to govern and manage within their homeland. Kaitiakitanga is to keep, guide and watch, preserve, and shelter resources. This notion is now included in many coucnil and government management strategies. This further acknowledges the active protection and responsibility for natural and physical resources by tangata whenua and considered in New Zealand resource decisions (Resource Management Act 1991). Essentially kaitiakitanga towards the natural environment ensures that the actions of people do not compromise the life-supporting capacity of the environment (Lenihan, 2010 In: Environmental Canterbury, 2010b), and the life-essence known as Mauri.

Mana Whenua and especially kaitiaki of the community have a specific integrated relationship and understanding of the natural environment through whakapapa. Under section 6(e) of the Resource Management Act 1991 “the relationship of Māori and their

[5] Includes Ihutai/Avon-Heathcote Estuary, Te Oranga/ Horseshoe Lake, Puari/Banks of the Avon River where the High Court now sits, Otautahi – as the traditional kainga where Kilmore Street presently exist, Oruapaeroa/ Travis Swamp, Te Kai a Te Karoro/Jellicoe Park now sits, Putaringa-motu/Riccarton Bush, Waitakari/now Bottle Lake, Ohikaparuparu beach near Sumner.

culture and traditions with their ancestral lands, water, sites, wāhi tapu and other taonga" is a matter of national importance (Harmsworth, 2002). It is important to have Māori input within integrated environmental monitoring programmes, and where Māori can develop their own approaches (Harmsworth, 2002).

The State of the Takiwā (Region) is an example of a parallel document to that of the National State-of-the-Environment, where tangata whenua conduct cultural monitoring and reporting of the health of the environmental (Te Rūnanga o Ngāi Tahu, 2004). This has been conducted in Te Ihutai Catchment (Pauling *et al.*, 2007), as well as Cultural Health included in the State of the Lake and Future Management of Te Waihora/Lake Ellesmere (Pauling and Arnold, 2009). Furthermore, this is an important way for tangata whenua to report on the environment from their world view or perspective.

In New Zealand, recent indigenous methodology has been developed, to measure the cultural health index (Tipa and Teirney, 2006a) of waterways and their food resources, cultural well-being (Panelli and Tipa, 2009), and by using holistic approaches to customary fisheries management (Hepburn *et al.*, 2010). The local knowledge and management process within customary evaluations could further inform natural resource management, however to date has been little research undertaken in this area.

1.4.3. On contaminants

The modern settlement and development of Christchurch city has had a dramatic impact on catchment-wide health, and especially the values of tangata whenua, and Mana Whenua that are associated with the waterways. Due to drainage, the wetlands are no longer evident, especially as places of mahinga kai (Tau *et al*., 1990). Today, the water quality of both Ōtākaro and Ōpāwa Rivers is affected by urban run-off of residential and industrial areas, with oil "spillages" also a concern into these two rivers (Tau *et al*., 1990; Pauling *et al*., 2007). Furthermore, the low state of the takiwā of Te Ihutai Estuary is a result of the absence of water flow, the influence of direct or visible stormwater inputs or wastewater discharges, and the extreme sedimentation (Pauling *et al*., 2007). Stormwater from urban catchment discharges into receiving waterways with a significant amount of pollutants of various forms (Brinkmann, 1985). The pollutants may be organic materials, plant nutrients, bacteria, or substances that are harmful to the ecosystem life such as certain heavy metals and hydrocarbons (Brinkmann, 1985). These are then transported down the waterways, to accumulate in the waterway environments where particulate material is deposited and remains for relatively long periods.

The three most common metal contaminants, zinc (Zn), copper (Cu), and lead (Pb), end up in the urban waterways in Christchurch and around New Zealand (Suren and Elliot, 2004; Zanders, 2005; Adams *et al.*, 2007). These contaminants are usually sourced from vehicle tyres and brake linings that accumulate on paved surfaces, which are washed off into waterways during rainfalls (Zanders, 2005).

Table 1.1. Priority listing of elements and human-health benefits (LeBlond, 2009)

Element	Priority List of Hazardous Substances Ranking a	Human-health Benefit (Toxicity and Carcinogenicity) b	Summary of Bioaccumulation, Bioconcentration, and/or Biomagnification Potential
Arsenic (As)	1st	None (Toxic)	Bioconcentrates
Cadmium (Cd)	7th	None (Possible carcinogen)	Bioaccumulates, bioconcentrates, may biomagnify
Chromium (Cr)	Cr (IV) 18th Cr 77th	Cr(III) Essential trace element Cr(IV) None (Neurotoxic carciogen)	Bioconcentrates
Cobalt (Co)	49th	Essential trace element	Bioaccumulated and bioconcentrates
Copper (Cu)	128th	Essential trace element	May bioaccumulate
Lead (Pb)	2nd	None (Neurotoxic)	Bioaccumulates and bioconcentrates
Mercury (Hg)	3rd	None (Toxic)	Bioaccumulates, bioconcentrates and biomagnifies
Nickel (Ni)	53rd	None (Neurotoxic)	Unknown
Potassium (K)	Radioactive form – (^{40}K) 217th	Essential trace element	Unknown
Rubidium (Rb)	Not listed	None (Generally nontoxic)	Unknown
Zinc (Zn)	74th	Essential trace element	Bioaccumulates and bioconcentrates

a - Agency for Toxic Substances and Disease Registry (ATSDR). 2007. 2007 CERCLA priority list of hazardous substances that will be the subject of toxicological profiles and support document. U.S. Department of Health and Human Services, Agency for Toxic Substances and Disease Registry, Division of Toxicology in cooperation with the U.S. Environmental Protection Agency, Atlanta, Georgia.
b - Canadian Council of Ministers of the Environment (CCME). 2009 Update. Canadian Environmental Quality Guidelines. Canadian Council of Ministers of the Environment, Winnipeg, Manitoba.

1.4.4. On contaminant accumulation in food

The intake of the edible parts of animals and plants by humans is one of the most important pathways for trace metals to harm human health. The speciation of the metal determines mobility, metal bioavailability and toxicity (Landner and Reuther, 2004). Metal speciation depends on the site-specific seasonal and spatial variations existing in a particular water, sediment or soil system (Landner and Reuther, 2004). The elements As, Cd, Pb, Cr, Hg, and Ni are of great concern because of they because of their toxicity to human health and other organisms, especially those are able to biologically accumulate and magnify (see Table 1.1). Pb and cadmium (Cd) are not essential elements for plants, and along with cadmium are toxic to human health and other organisms. Although certain metals above are not essential elements for plants, plants take up the metals and accumulate them in their edible parts in various concentrations. Certain heavy metals can be positive to organisms if they are essential for functions, or else negative by impairing an organism function, or have a toxic effect.

The Australian and New Zealand Environment and Conservation Council (ANZECC) Guidelines for Fresh and Marine Water Quality (2000) prescribe the trigger levels or the threshold levels of contaminants. The contaminant concentrations in the water can be assessed with reference to these trigger level values, above which intervention is recommended. See Table 1.2 for selected toxicities for the three primary metal contaminants along with ANZECC (2000) protection levels. There is no protection level developed yet for the sediment-bound contaminants, however ANZECC has prescribed a set of interim sediment quality guidelines (ISQG) (See Table 1.3).

Table 1.2 Trigger values for metals and metalloids at alternative levels of protection for fresh and marine waters. Values in grey shading are the trigger values applying to typical slightly-moderately disturbed systems (ANZECC 2000: please refer to this document for footnotes A-C).

Chemical		Trigger values for freshwater (µgL^{-1})				Trigger values for marine water (µgL^{-1})			
		Level of protection (% species)				Level of protection (% species)			
		99%	95%	90%	80%	99%	95%	90%	80%
METALS & METALLOIDS									
Aluminium	pH >6.5	27	55	80	150	ID	ID	ID	ID
Aluminium	pH <6.5	ID	ID	ID	ID	ID	ID	ID	ID
Antimony		ID	ID	ID	ID	ID	ID	ID	ID
Arsenic (As III)		1	24	94 [C]	360 [C]	ID	ID	ID	ID
Arsenic (AsV)		0.8	13	42	140 [C]	ID	ID	ID	ID
Beryllium		ID	ID	ID	ID	ID	ID	ID	ID
Bismuth		ID	ID	ID	ID	ID	ID	ID	ID
Boron		90	370 [C]	680 [C]	1300 [C]	ID	ID	ID	ID
Cadmium	H	0.06	0.2	0.4	0.8 [C]	0.7 [B]	5.5 [B, C]	14 [B, C]	36 [B, A]
Chromium (Cr III)	H	ID	ID	ID	ID	7.7	27.4	48.6	90.6
Chromium (CrVI)		0.01	1.0 [C]	6 [A]	40 [A]	0.14	4.4	20 [C]	85 [C]
Cobalt		ID	ID	ID	ID	0.005	1	14	150 [C]
Copper	H	1.0	1.4	1.8 [C]	2.5 [C]	0.3	1.3	3 [C]	8 [A]
Gallium		ID	ID	ID	ID	ID	ID	ID	ID
Iron		ID	ID	ID	ID	ID	ID	ID	ID
Lanthanum		ID	ID	ID	ID	ID	ID	ID	ID
Lead	H	1.0	3.4	5.6	9.4 [C]	2.2	4.4	6.6 [C]	12 [C]
Manganese		1200	1900 [C]	2500 [C]	3600 [C]	ID	ID	ID	ID
Mercury (inorganic)	B	0.06	0.6	1.9 [C]	5.4 [A]	0.1	0.4 [C]	0.7 [C]	1.4 [C]
Mercury (methyl)		ID	ID	ID	ID	ID	ID	ID	ID
Molybdenum		ID	ID	ID	ID	ID	ID	ID	ID
Nickel	H	8	11	13	17 [C]	7	70 [C]	200 [A]	560 [A]
Selenium (Total)	B	5	11	18	34	ID	ID	ID	ID
Selenium (SeIV)	B	ID	ID	ID	ID	ID	ID	ID	ID
Silver		0.02	0.05	0.1	0.2 [C]	0.8	1.4	1.8	2.6 [C]
Thallium		ID	ID	ID	ID	ID	ID	ID	ID
Tin (inorganic, SnIV)		ID	ID	ID	ID	ID	ID	ID	ID
Tributyltin (as µg/L Sn)		ID	ID	ID	ID	0.0004	0.006 [C]	0.02 [C]	0.05 [C]
Uranium		ID	ID	ID	ID	ID	ID	ID	ID
Vanadium		ID	ID	ID	ID	50	100	160	280
Zinc	H	2.4	8.0 [C]	15 [C]	31 [C]	7	15 [C]	23 [C]	43 [C]

Table 1.3. Interim sediment quality guidelines (ISQG) (mg kg^{-1} dry wt), primarily adapted from Long et al., 1995 (ANZECC, 2000)

Contaminant	ISQG-Low (Trigger value)	ISQG-High
METALS (mg/kg dry wt)		
Antimony	2	25
Cadmium	1.5	10
Chromium	80	370
Copper	65	270
Lead	50	220
Mercury	0.15	1
Nickel	21	52
Silver	1	3.7
Zinc	200	410
METALLOIDS (mg/kg dry wt)		
Arsenic	20	70

1.4.5 On waterway management for mahinga kai values

Historical accounts show there was no importance towards mahinga kai for Ngāi Tahu by local government. One example is where Ngāi Tahu was shut out of the city development and the management of the Ihutai catchment (Tau *et al*., 1990; Tau, 2000; Matunga, 2000). This section reflects a change in the approach of the City Council in the goals of management and inclusion of Mana Whenua goals and values.

The Christchurch Regional Council, Environmental Canterbury, manage the waterways from the streams to the estuarine area. The Canterbury Waterway Management Strategy (CWMS)[6] provides an opportunity for local communities to contribute to the identification of shared values at a local and regional level (Environmental Canterbury, 2012).

Within the campus itself, the management and future of potential mahinga kai sites is governed the University itself. The alignment of the relationship between the CWMS and the Campus Master Plan actions will be essential towards mahinga kai, and overall the mana of Mana Whenua.

The Campus Master Plan (University of Canterbury, 2012) outlined the goals and strategies where priority of campus spaces is:

- A positive and inclusive student experience
- A positive University culture and identity
- Empowering 21st century learning
- Supporting and celebrating Māori and Pacific communities
- Improved connections to industry and the community.

The Wai-utuutu Stream, as part of the Ōtākaro River catchment sits within this strategy, as part of the West-Melton Zone Implementation Programme (ZIP). The most recent document by Environmental Canterbury (2012) states Ngāi Tahu should be able to play an active role in decision-making and achieve a range of outcomes in their kaitiaki role. It is acknowledged that the CWMS governance of water at zone, regional and national scales will have impacts on the ability of Ngāi Tahu to act as tangata tiaki (Environmental Canterbury, 2012).

Under the Resource Management Act (RMA, 1991), the duties associated with kaitiakitanga include:

a) Restoring and rehabilitating degraded mahinga kai sites;

b) Assessing the cultural implications of proposed developments, including preparing cultural impact assessments;

c) Lodging submissions and presenting evidence on resource consent applications and plan development processes;

d) Forming constructive relationships with environmental agencies such as councils, the Department of Conservation and Fish and Game.

[6] The CWMS, provides this opportunity through the establishment of Zone Committees and the development of Zone Implementation Programmes (ZIP)

2 METHODS

The methodology involved the review of both Mātauranga Māori and scientific literature that focussed on cultural ecological indicators and values, stormwater input, and scientific ecological indicators. Cultural health index findings were sought of important sites of harvest to understand the depth of research involved. This was also done to address the role of Mana Whenua as kaitiaki relating to mahinga kai. To establish a framework of Mātauranga Māori methodology this project was informed in consultation with mentor Te Maire Tau of the Ngāi Tahu Research Centre, as well in context with articles of relevance to Ngāi Tahu environmental and cultural values.

2.1 Review approach

A systematic approach was undertaken to review an extensive range of literature, taking into account the history of the area and the relevant management priorities, and technical reports by the local government. The publications were accessed in hard-copy reports and guidance books, through the web-based Canterbury University databases of Scopus, Science Direct, Web of Science; and reports published on the webpages of: Te Rūnanga o Ngāi Tahu, research papers available on the research department webpages of the University of Canterbury, Environmental Canterbury Regional Council, and the Ministry for the Environment.

The background research included the historical accounts of local urban waterways, cultural values associated with Mahinga Kai and a review of contaminants. In particular, the contaminant study reviewed the nature of physiological response (such as biological accumulation and toxicity) to plants and fish species, and whether the implications this has for Mahinga Kai as a place, space, and its associated species.

Finally, this was used to create and draw discussions on the options to introduce mahinga kai species and the associated cultural environmental values within the University Campus waterways.

3 RESULTS OF REVIEW

This chapter presents the findings and literature review of the cultural environmental values, the contaminant assessment, and the Campus Master Plan. This literature review is used to assess whether mahinga kai is feasible within the Campus of the University of Canterbury, specifically in the Wai-utuutu Stream.

3.1 Wai-utuutu Stream history

The Wai-utuutu Stream has been the focus of restoration projects since 1996, with increased participation in the management, research and development of the campus waterways across time. The Waterways Advisory Committee was formed with the objective to have representatives of all interest gropus to guide the vision and actions taken towards achieving sustainable management of the waterways flowing through the University of Canterbury (Hewson *et al.*, 2006). The restoration programme included riparian planting, habitat reconstruction and a programme to manage aquatic weeds (Environmental Canterbury, 2010).

Since then, the stream has become an attractive landscape feature with improved stream habitat and the water flow (Environmental Canterbury, 2010). However, the study on the efforts of the rehabilitation towards stream recovery showed that the amount of deposited sediment was high, whereas algae, fungi and microbes on the substrate was consistently low (Blakely *et al.*, 2003), and that ecological rehability had not been achieved (McIntosh, 2007). It is suggested that the accumulation of factors affect the stream, such as a lack of continous high water quality, as this deteriorated during spates and low flows; the physical habitat conditions were variable, the presence of dispersal barriers, siltation build up, and the accumulation of organic matter (McIntosh, 2007). Further research reported that the stormwater high heavy metal input concentrations (Farrant, 2006; Taffs, 2007), and air-conditioned metal input (O'Sullivan *et al*., 2012) in combination with the current stormwater management, sedimentation, has affected stream health and integrity (Blakely and Harding, 2005; O'Sullivan *et al*., 2012).

3.2 Current values and limitations

There was no specific information on the cultural values and ecological knowledge to assess the standard for mahinga kai according to Mana Whenua, in this stream or in the Ōtākaro Catchment. However, given the nature of the stream and its catchment some assumptions can be made.

3.2.1. Cultural values: Mahinga Kai and Mana Whenua

It would be expected that the migratory species that were present in traditional sites such as tuna, kanakana and inanga would be present in the Wai-utuutu Stream by migrating up the Ōtākaro River and to the tributaries. Research has shown that there has been a loss of

sensitive species since the 1980s, and the translocations of crayfish and mudfish have failed (McIntosh, 2007). There is no report on the specific mahinga kai or mana whenua values or input in the University Campus waterways. Without a full assessment of the physical environment itself, it is assumed that the Mauri of these waterways, including Okeover Stream is not 'alive' (Mauri Ora), and thus an unhealthy place, Mauri Mate, for mahinga kai species as evident in the lack of sensitve freshwater species (crayfish, mudfish, macro-invertebrates: McIntosh, 2007, Blakely and Harding, 2005).

Hewson *et al*. (2006) has written that the waterway use has been the Māori Department growing and softening of harakeke/flax (*Phormium tenax*) for weaving, while watercress was harvested for food by Asian students and local residence. It is unsure of the current safety of softening flax. The gathering and especially the consumption of watercress is not recommended.

Further urban waterways do not show positive cultural values. The cultural environmental health assessment in Te Ihutai give the indication that this estuary, that acts as a sink to the two major rivers, Ōtākaro and Ōpāwa Rivers, has poor health (Pauling *et al.*, 2007). Te Ihutai, has was the site of received sewage waste from the city, and Ōtākaro and Ōpāwa Rivers have had industrial and residential pressures from the environment. However, this has prevented mana whenua from conducting mahinga kai, and it seems this is the case at the University Campus.

3.2.2 Cultural values: Ecology

Only two fish species upland bullies (*Gobiomorphus breviceps*) and long finned eels (*Anguilla dieffenbachia*) were found in the Okeover, compared to Waimairi stream that also had brown trout (*Salmo trutta*) (Blakely *et al.*, 2003). Both the Wai-utuutu fish species were recorded below the Wai-utuutu community gardens, with none found in the upper reaches (Blakely *et al.*, 2003). The level of tolerance to metals-polluted streams and water chemistry varies in New Zealand's freshwater species. The tolerance of these species to waterway contaminants and water chemistry may determine their presence and distribution accordingly.

The presence of heavy metals (Cu, Zn, Cd, and Pb) and deposited sediment in the Wai-utuutu Stream have been suggested to impact on its ecology, with the decline in benthic invertebrates abundance and diversity up-stream compared to downstream (Blakely *et al.*, 2003). Recent studies of Wai-utuutu have shown that the metals Zn, Pb, and Cu, are discharged into the stream from stormwater especially during storm events, from the University car parks, and the air-conditioning pipes of water input (Farrant, 2006; Taffs, 2007; O'Sullivan *et al*., 2012).

Hickey and Clements (1998) reported that streams in the Coromandel Peninsula, in what were historically mined catchments and had high concentrations of metals including Cd, Cu, Pb and Zn, were low in invertebrate species richness (<5 taxa), had reduced abundance of metal-sensitive mayflies, and were dominated by metal-tolerant orthoclad chironomids. Koaro (*Galaxias brevipinnis*) have rarely been found in acid or metal-polluted systems, and seem to be restricted to relative pristine waters (Harding, 2005). Common smelt (*Retropinna*

retropinna) are pollutant-sensitive, inanga have intermediate tolerance limits, whereas short-fin and long-fin eels are highly tolerant (Richard and Taylor, 2002) and found in where heavy metals have been detected (Stewart *et al.*, 2010).

The temporal relationship of water chemistry (e.g., pH) and the number of taxa over time in Wai-utuutu Stream in 1980, 1990, 2000, and 2006 data sets, showed little variation over time, and yet the total number of total caddis data varied across sites (Harding, 2007). In the West Coast waterways, short-fin and long-fin eels have been found in acidic waters (pH<5) and acidic to alkaline waters (pH 4.4-8.1) respectively (Greig *et al.*, 2010). Bluegill bullies (*Gobiomorphus hubbsi*) and torrentfish (*Cheimarrichthys fosteri*) have been found in even higher acidity (minimum pH of 6.5 for both; Greig *et al.*, 2010), and inanga, banded kokopu and giant kokopu (*Galaxias fasciatus* and *G. argenteus*, respectively) seem well adapted to the naturally low pH streams (Collier *et al.*, 1990; Greig *et al.*, 2010).

Overall, species presence does not seem to be affected as much by the water chemistry, as they are to the streams containing trace metals. However, it must be noted that food sources for many benthic invertebrates, the total biofilm and periphyton, were also relatively low in the Wai-utuutu (Blakely *et al.*, 2003).

3.2.3 Trace metal concentrations

The concentration of certain metals reported in the Wai-utuutu Stream water has been shown to be above the ANZECC (2000) trigger levels for freshwater (Table 1.2) and in sediments, above the ANZECC Interim Sediment Quality Guidelines (ISQG; Table 1.3) for the protection of freshwater species. The contaminants Zn, Pb, and Cu, that could potential be toxic to aquatic organisms are discharged into the stream from stormwater especially during storm events, from the University car parks, and the air-conditioning pipes of water input (Farrant, 2006; Taffs, 2007; O'Sullivan *et al*., 2012).

Farrant (2006) studied the level of contaminants during stormwater events, to compare to baseflow levels, and reported that total Cd and total Ni concentrations in the water were either below the detection limits, or below the 99% ANZECC trigger values. Dissolved Cd and dissolved Ni were also low in concentration at most sites across the storm sampling events (Farrant, 2006). Therefore, Cd and Ni were not considered to be of concern. However, the concentrations of total Zn and Cu exceeded the 80% ANZECC trigger values in all samples, and total Cd, and Cr concentrations were detected above the 90% trigger values for most samples (Farrant, 2006).

Taffs (2007) also measured the stormwater level of contaminants at one sample site to compare to Farrant's (2006) report, also finding that dissolved and total Ni levels during storm events were below the 99% ANZECC trigger value. Dissolved Cd was below the detection levels during the storm events, but Cd peaked above the 95% ANZECC trigger value. Taffs (2007) findings confirmed that Cu, Zn and Pb were at concerning levels in stormwater sample; total and dissolved Cu and Zn peaked above the 80% ANZECC trigger value, total Pb above the 80% threshold (base flow level values were also high and above the 90% trigger levels; and dissolved levels were above the 99% trigger levels (Taffs, 2007).

The concentration of contaminants in the sediment showed that Zn, Cu were above the ISQG, while As and Ni were below the ISQGs (Taffs, 2007). Cu, Zn, and Pb are potentially toxic with high levels in both water and sediment samples in the Okeover Stream (Taffs, 2007).

The most recent study by O'Sullivan et al. (2012) measured the contaminant level of the air-conditioning and stormwater discharges and showed that the concentrations of Zn, Cu and Pb exceeded relevant guidelines for the protection of 90% of aquatic species (O'Sullivan *et al.*, 2012). Further to this, the report on the contaminants in the air-conditioned water input into the stream showed that there was an 11-fold greater annual Cu load to the stream from air-conditioning discharge, compared to stormwater runoff (O'Sullivan *et al.*, 2012). The overall conclusion was that these four metals; Zn, Pb, Cu and Cr, were potentially harmful to aquatic organisms in this waterway.

3.2.4 Metal accumulation in plants and fish

The biological concentration of metals within plant and fish species varies according to the concentration of the metals and the ability to accumulate metals from the surrounding environment, as well as the transportation of the metals in the tissue of the plant.

In the South Island of New Zealand, watercress (*Rorippa nasturtium*) has been shown to accumulate the elements As, Cd, Cu, Pb, Zn, P in Lincoln (Hunt, 2011); and watercress[7] (*Nasturtium nasturtium*) As, Cd, Cu, Cr, Zn in Arowhenua rohe (Te Muka to Timaru region; Stewart *et al.*, 2010). This shows that watercress is able to accumulate a range of metal species.

The results that follow further show the difference in the amount of metal concentration accumulated by the watercress as well as mahinga kai species (Stewart *et al.*, 2010). The order of the median metal concentration for each species (mg/kg dry weight) across sites was as follows:

- pātiki/black flounder (*Rhombosolea retiaria*) with Zn (31) > Cu (1.2) > As, Ni, Hg (all less than 0.60)[8], with no detection of Cd and Cr;
- brown trout (*Salmo trutta*) with Zn (16) > As (1.55) > Cu (1.2) > Hg, Ni, (all less than 0.60) > Pb, Cd, Cr (not detected);
- watercress (*Nasturtium officinale*) with Zn (43) > Cu (8.3) > Ni, Pb (~1.0) > Cr, As, Cd (less than 0.7) > Hg (not detected);
- short-fin and long-fin eel (*Anguilla Australia*, and *A. dieffenbachii* respectively) with Zn (34) > Hg (1.1) > Cu (0.87) > Ni, Cr (less than 0.4) > Pb, Cd, As (not detected).

International studies have demonstrated that aquatic plant species vary in their biological accumulation of metal species. One such study compared accumulation ability of two

[7] The watercress reported is the same species, with synonyms being *Nasturtium nasturtium-aquaticum* (L.), *Rorippa nasturtium-aquaticum* (L.), and *Sisymbrium nasturtium-aquaticum* (L.).
[8] > 'greater than'

riparian species Chinese mat grass (*Cyperus malaccensis*) and Bulrush (*Scirpus tripueter*) (Zhang *et al*., 2010). This showed that the plants absorbed the same metal species however they varied in the accumulation of the metals. *C. malaccensis* had accumulated higher concentrations of Cu, Ni and Zn, and lower concentrations of Cd, Cr, and Pb to that of *S. tripueter* (Zhang *et al*., 2010). Another study showed that mercury (Hg) uptake across four species of aquatic plants, went from order of highest to lowest uptake rate, with water lettuce (*Pistia stratiotes*), water hyacinth (*Eichornia crassipes*), taro (*Colocascia esculenta*) and then zebra rush (*Scirpus tabernaemontani*) (Skinner *et al.*, 2007). This also shows that these aquatic plants can reduce the Hg concentration in the water via root uptake and accumulation, with water lettuce and water hyacinth reported as most effective (Skinner *et al.*, 2007).

Another factor in metal uptake is the accumulation into different parts of the organisms, for instance the root, the stem or other. Where the metal concentrations in water and plant root are the same, or have a relationship, shows the plants efficiency to uptake metal (Dushenkov *et al.*, 1995; Skinner *et al.*, 2007). Studies have further shown that plants may accumulate higher metal concentrations in the roots compared to their stem, or the root compared to the leaves (Cardwell *et al.*, 2002; Chagué-goff, 2004). In Chagué-goff (2004) rushes (*Juncus* sp.) and lesser loostrife *(Lythrum hyssopifolia*) had accumulate higher metal concentrations in their roots than stems. The uptake ratio across aquatic species for the metals Cd, Cu, Pb, and Zn, showed that roots had a higher uptake than stems/rhizomes[9], and roots higher than the leaves (Cardwell *et al.*, 2002). However, there was no consistent trend when measuring the rate of uptake from the roots to leaves across plants (Cardwell *et al.*, 2002). For example the Cumbungi (*Typha* spp.) had an uptake ratio of roots>rhizome>leaves compared to Knotweeds (*Persicaria* spp.) with roots > leaves > steams uptake (Cardwell *et al.*, 2002). Although these plants differ in the amount of uptake by either the stem or the leaves, it is shown that the roots still have the highest concentration of metal uptake.

In comparison to the root receiving the highest metal uptake, a study of vegetables showed that the measured transfer factor of the metals Cd and Pb from the soil-to-leaves were higher in leafy vegetables (Chinese cabbage, pakchoi, water spinach) than those for the non-leafy vegetables (Wang *et al.*, 2006).

[9] '>' greater than, e.g. "roots > stems", in this case means, the uptake rate where "roots greater than stems"

4 DISCUSSION

The overall goal for this literature review was to assess whether mahinga kai is feasible within the Campus of the University of Canterbury, specifically in the Wai-utuutu Stream.

4.1 Mana Whenua and Mahinga Kai Assessment of Wai-utuutu Stream

The Māori values of mauri, mana, manaaki, rangatiratanga, kaitiakitanga were introduced in the first section in their interwoven nature to each other through tikanga Māori and expressed in practices such as Mahinga Kai. Overall, these concepts express how mahinga kai through the waterways promotes identification and wellbeing for Māori, through the capacity to provide places of continued and evolved customary practices, to gather food, and resources. Mahinga kai is considered by Ngāi Tahu to be, in today's language, the principal 'environmental indicator' in natural systems (Environment Canterbury, 2011).

In Wai-utuutu stream, there is a lack of sensitive species present and a high metal input from stormwater. The absence of the metal-sensitive species such as *Galaxias* species and more moderate tolerance of metals, inanga, within the Wai-utuutu stream is a sign of at least moderate levels of metals. Heavy metal input in the stream could be influencing the lack of increase in invertebrate species (Blakely and Harding, 2005), as it has been shown that elevated levels of copper and zinc in sediment adversely affect estuarine infauna (Fukunaga *et al.*, 2011).

Historical and continued actions have depleted the environmental health of this waterway for the practice and knowledge of mahinga kai, with far reaching implications on knowledge transfer, knowledge creation, cultural identity, and marginalisation of places of practice, and perhaps today higher pressures on 'others' hapū boundaries of resources.

4.2 Bio-accumulation & remediation of metals in Wai-utuutu Stream

Watercress growing in the stream is likely to be unsafe, as it accumulates a range of contaminants (Hunt, 2011; Stewart *et al.*, 2010), including Cd, Cu, Pb, Zn which are reported to be elevated in Wai-utuutu Stream.

The state of dissolution of metals poses risks to the remediation of the waterways from metal concentration and absorption. The toxicity of Cu to aquatic biota is critically dependent on the bioavailability of the copper in the water. Decreasing the level of Cu input by improving treatment may be required. Pb was also a concern, as it may be flushed from sites of sediment deposition easily by high flow events (O'Sullivan *et al.*, 2012). This may have implications for removing lead in any treatment without the risk of it remobilising O'Sullivan *et al.* (2012). O'Sullivan *et al.* (2012) suggested that Zn, and Cu were mainly dissolved species, possibly enhancing metal bioavailability, though elevated metal concentrations were also found throughout the stream sediments.

Aquatic plants could reduce the metals effectively in the water via root uptake and accumulation (Skinner *et al.*, 2007), and it is possible that watercress and other species that have higher uptake rate be investigated for phytoremediation of the waterway. Watercress could also be maintained along the sides of some reaches to trap silt, and so prevent sediment from further smothering the streambed but provide substrate for re-vegetation with native species (Hewson *et al*., 2006). Therefore, this remediation option would include keeping the sediment in place, further supporting treatment of stormwater and air-conditioned water input, before addition into the waterway.

Potential treatments to remove pollutants include constructed wetlands to remove and immobilise copper and zinc from stormwater, by the capturing fine suspended particulates and associated copper and zinc within the network of plant roots and biofilms (Headley and Tanner, 2006). This requires an understanding of biological absorption and uptake to remove contaminants, and of the toxicity of metals to aquatic species (Headley and Tanner, 2006). Although wetland systems that have been used in New Zealand have historically been focussed on excess nutrient treatment (Headley and Tanner, 2006), there is now more interest in passive (wetland) treatment of metal-rich stormwater and mine waste waters.

Finally, as a further restoration benchmark, waterways that meet the water quality guidelines of ANZECC (2000) will be suitable for inanga (Richard and Taylor, 2002). If it the water quality and habitat is good for sensitive species such as inanga, it is likely that this would benefit the waterway communities, and should be set as a benchmark for waterway habitats. Inanga streams typically contain areas with low water velocity and cover, that have low sediment transport rates and flood flows also (Richard and Taylor, 2002). Also important for inanga habitats are the presence of good riparian vegetation, woody debris, or macrophytes to provide cover, meanders and pools for feeding (Richard and Taylor, 2002). Plants that create good cover for this type of habitat are pastoral grasses (left to grow at the edges of the waterway), toetoe, flax, ferns, and watercress (Richard and Taylor, 2002). Streams choked with vegetation, such as *Glyceria* (mannagrass) and gorse, are not good inanga habitats (Richard and Taylor, 2002).

4.4 Answering the specific study questions

4.4.1 Study Question 1

How can the university campus produce food in a way that acknowledges and strengthens Mana Whenua as kaitiaki?

There has been no cultural health report on the UC campus waterways. However, the low water flow and inconsistent water quality in Wai-utuutu is a poor level indicator for stream health (Tipa and Teirney, 2006). The results illustrate that the freshwater species are likely to be impacted by trace metals exceeding the ANZECC (2000) levels of protection. Māori prefer stormwater to be treated (preferably land-based) before discharge into natural waterways because they believe the mixing of water and waste pollutes mauri (Environment Canterbury, 2011).

The literature review also suggests that certain mahinga kai species are tolerant to metal-contaminated waterways, such as watercress (Stewart *et al.*, 2010; Hunt, 2011), short-fin and long-fin eels (Richard and Taylor, 2002; Greig *et al.*, 2010; Stewart *et al.*, 2010). Harvest as mahinga kai could potentially pose concern to those that consume them. Further to this, as an introduced plant, watercress can overgrow and limit other indigenous biota. The bio-accumulation of metals by species, along with the implications of this, are further discussed below.

The current waterway frameworks of Mana Whenua values for mahinga kai and catchment wide health such as Mauri has not been included within previous Campus waterways research. The correct procedure, that is tikanga Māori by Mana Whenua, should be included within the current and future framework of assessment, monitoring and decision making. The management within the University Campus should also meet the goals of Ngāi Tahu policy in terms of the waterway and cultural health. In relevance to waterway and contaminant input, Environmental Canterbury (2012) kaitiakitanga targets included to work towards Ngāi Tahu policy issues of:

- Environmental flows that afford protection to in-stream values and
- Direct discharge of point source contaminants to water The unnatural mixing of water sourced from different water bodies
- Address non-point pollution through a range of measures including regulatory control

The inclusion of these value systems and world view into the practices of environmental monitoring leads to greater accountability, to longer time frames/generations of knowledge and practices compared to the current short term local council frameworks. Furthermore, mahinga kai strengthens the associated connection of Mana Whenua to the environment through the rangatiratanga in management of waterways**.** As a result, the environment could be healthy, iwi and hapu could harvest natural resources and other values, such as recreational and ecological health, could be available for urban communities (Environment Canterbury, 2011).

4.4.2 Question 2

What are the opportunities for doing this at the University of Canterbury?

Although traditional mahinga kai may not be feasible, the Wai-utuutu waterway could be used as a place of learning and studying the potential of mahinga kai as re-mediators, and as 'green engineers' effectively removing the metal from the waterways. This role of remediation would need to be disconnected from mahinga kai. This will become a place of traditional ecological knowledge with holistic management and whole ecosystem function. The roles for indigenous species such as bio-remediation, effects of urban environments, and further knowledge and education around cultural values are part of this knowledge base.

The aquatic species that may be viable for effective uptake of the specific metals that have been elevated in the Wai-utuutu Stream are listed in the Appendix B. The plant and metal for uptake are as follows: water spinach, *Ipomoea aquatic,* takes up Cd, Pb (Wang *et al.*, 2006); watercress takes up Cd, Pb, Cu, Zn (Stewart *et al.*, 2010; Hunt, 2011); taro, *Colocascia esculenta*, a wet-feet species, takes up Cd, Cu, Pb, Zn (Cardwell *et al.*, 2002), rushes, *Juncus sp.* and lesser loostrife, *Lythrum hyssopifolia* takes up Cu, Zn, Pb (Chagué-goff, 2004). It may be too cold in Christchurch to grow species like taro, such as the case with kumara. However, kumara were found in the Ōtākaro river mouth (Tau *et al.*, 1990).

The Wai-utuutu Stream within the University Campus provides can be a place of learning and testing of ecological and cultural ecological health values, according to the restoration and research that has taken place at the Wai-utuutu Stream. This stream is still used to soften harakeke outside the Ngāi Tahu Research Centre and Te Aotahi (Māori and Indigenous Studies Department). The integration of Mana Whenua concepts and indicators into the Campus environment would benefit the Campus Master Plan objectives. In order to promote mahinga kai that is safe, the option of utilising space around Te Ao Mārama to develop mahinga kai on land is suggested. The relationship between Mana Whenua and the natural environment as well as the decision making will then be re-established, and developed according to acknowledge whakapapa.

Furthermore, this supports the Campus Master Plan options of making “better use of existing space” (University of Canterbury, 2012). The Campus Master Plan is providing improvement to changes and inclusion of more connections both recreational and customary to the campus environment, places of cultural centres, and heart hubs for the Campus, it is highlighted through out the interview section that the lack of physical marae and food prices and scarcity are major concerns for both Māori students in the former, and generally students across the board in the latter reference (Arbouw and Ballantine, 2010).

A physical whare nui (meeting house) building is not supported here it is the decision of Mana Whenua to establish and carry the role of marae decisions in their region. The history and concept of marae have changed over time, with many views of it being only represented as a meeting house to physically represent identity. The University of Canterbury has two important whare, Te Akatoki: the Māori Students Association whare, and Aotahi: that houses the Department of Māori, Pacific and Indigenous Studies, the Ngāi Tahu Research Centre, the support staff for Māori students, and connects to the MacMillan Library. There is a wealth of knowledge and capability that exists here. These houses could ideally be transformed to represent the marae of contemporary environment, especially Te Aotahi/Te Ao Mārama, as it is a place of learning and sharing of information.

The lack of this identification as a space for marae emphasises that there may be disconnection of these spaces as hubs for their cultural and social interactions, and places of learning at the campus. Marae support and celebrate Māori communities through actively enabling traditional practices, mana towards those as hosts through their place and practicing of manaakitanga.

The meaning of marae is the physical space that encompasses a whare of sleeping and wānanga, to learn, with another whare for hosting and sharing of hospitality. Mahinga kai is a place and practice of marae tikanga. As the wellbeing of the hapū sits within the practicing

of tikanga, one being the role to practice kaitiakitanga, so too can Māori students and the wider community to learn and share within this largely urban, western Education Institution.

4.4.3. Question 3

What, if anything, has already been achieved in this vein?

There have been UC researchers involved in past restoration and research on the Wai-utuutu Stream, with detailed ecological information collected yearly by the Freshwater Ecology Research Group (FERG) in the School of Biology at UC, and water and sediment quality research under taken by Civil and Natural Resource Engineering (CNRE). There is currently no report on cultural assessment and values for this stream either. However, there exist many riparian species that could support high level of restoration, including flax, ferns, and watercress which are traditional and introduced wild kai and cultural resources (Richard and Taylor, 2002).

In terms of mahinga kai species, there was no specific research available. However, in terms of land-based activities such as gardening, the Okeover Community Garden exists as the main local community and University-driven garden site. There are also edible species that have existed for a long time, such as the walnut trees of at least thirty years, near the main library, and planted pepper trees (*Pseudowintera colorata*) across campus and at Te Ao Mārama (Cone, pers. comm. 2013). Recent additions to the idea of edible plants at the University Campus is the planting of cranberry and lemon trees outside University Student Services, as well as cranberry, lemon, pear, and feijoa trees outside Café 1894 (Cone, pers. comm. 2013). The concern around any additional gardens or herb boxes may be the maintenance and responsibility within a transient student environment (Cone, pers. comm. 2013).

4.5 Limitations of the current study

A limitation of this study is that there is very little information on other study areas within Christchurch for a comparison of cultural health values, especially of stream health. There was also little information on heavy metal assessment with regard to mahinga kai and non-mahinga kai areas in Christchurch. It is recommended that the knowledge base of mahinga kai in urban areas be developed as well as extended across waterways, as a standard of waterway health.

In New Zealand, recent indigenous methodology has been developed to measure the cultural health index (Tipa and Teirney, 2006b) of waterways and their food resources, cultural well-being (Panelli and Tipa, 2009), and using holistic approaches to customary fisheries management (Hepburn *et al.*, 2010). The local knowledge and management process within customary evaluations could further inform natural resource management, however to date little research has been undertaken in this area.

5 CONCLUSIONS

The feasibility of traditional mahinga kai in the University Campus stream Wai-utuutu is not supported by this study. The stream does not currently support many mahinga species and especially the water flow dependencies, for cultural health. More importantly it does not have sensitive species that are mahinga kai species or non-mahinga kai invertebrates. Waterways that meet the water quality guidelines of ANZECC (2000) are needed for inanga (Richard and Taylor, 2002), and to provide suitable water quality and habitat for other waterway communities, and should be set as a benchmark for waterway restoration.

There is, however, an opportunity to assess the role of mahinga kai as biological engineers to effectively remove metals in the waterway and along riparian zones, supporting past research recommendations to remediate the effects of stormwater in Wai-utuutu stream (Farrant, 2006; Taffs, 2007; O'Sullivan 2012). The waterway could be used as a place of learning and studying the potential of mahinga kai as re-mediators, and 'green engineers' effectively removing the metal from the waterways. Along with treating the stormwater input, certain plant species and shellfish species could also provide sunstrate stability. This is important, as disturbing the sediment beds could remobilise metals into the waterway.

Land-based mahinga kai is therefore recommended to fulfil the role of tikanga associated with marae and mahinga kai. This supports the Campus Master Plan to utilise existing space and enhance places of social and cultural hubs.The integration of Mana Whenua concepts and indicators into the Campus environment would benefit the Campus Master Plan objectives. For, the ability to promote mahinga kai that is safe, the option of utilising space around Te Ao Mārama to develop mahinga kai on land is suggested. The relationship between Mana Whenua and the natural environment as well as the decision making will then be re-established, and developed according to acknowledge whakapapa.

It is further recommended that consideration be given to applying the Cultural Health Index (Tipa and Teirney, 2006) by Mana Whenua, and to include this into future management and restoration of the stream. There are also other frameworks that guide decision-making and restorative processes such as the Mauri Model Decision Making Framework (Morgan, 2007).

REFERENCES

Adams, J., Mahar, T., and Broad, S. (2007) Monitoring stormwater discharge into the Avon River from the Fine Arts Carpark at the University of Canterbury for resource consent renewal. Report submitted in partial fulfilment of the requirements for the BE (Hons) Degree in Natural Resources Engineering, University of Canterbury.

Anderson, A.J. (1998) The welcome of strangers: an ethnohistory of southern Maori A.D. 1650-1850. Otago University Press in association with Dunedin City Council. Dunedin, New Zealand.

ANZECC (2000) 'Australian and New Zealand Guidelines for Fresh and Marine Water Quality'. Australian and New Zealand Environment and Conservation Council (ANZECC), and Agriculture and Resource Management Council of Australia and New Zealand (ARMCANZ). National Water Quality Management Strategy Paper No. 4, Volume 1, The Guidelines (Chapters 1 to 7).

Arbouw, P., Ballantine, P. (2010) Moderator Report, User's perspectives of non-educational facilities on the University of Canterbury Campus. University of Canterbury. http://www.canterbury.ac.nz/theuni/campus_plan/documents/CMP_Retail_Study.pdf

Blakely, T., and Harding, J. (2005) Longitudinal patterns in benthic communities in an urban stream under restoration. *New Zealand Journal of Marine and Freshwater Research* 39: 17–28

Blakely, T., Harding, J., McIntosh, A. (2003) Impacts of Urbanisation on Okeover Stream, Christchurch. Freshwater Ecology Research Group, Department of Zoology, University of Canterbury, New Zealand. Report 25 pages.

Brinkmann, W. L. F. (1985) Urban Stormwater Pollutants: Sources and Loadings. Water in the Urban Environment. *GeoJournal* 11(3): 277-283.

Cardwell, A.J., Hawker, D.W., Greenway, M. (2002) Metal accumulation in aquatic macrophytes from southeast Queensland, Australia. *Chemosphere* 48: 653–663.

Chagué-goff, C. (2005) Assessing the removal efficiency of Zn, Cu, Fe, and Pb in a treatment wetland using selective sequential extraction: A case study. *Water, Air, and Soil Pollution* 160**:** 161–179.

Collier, K. J., Ball, O. J., Graesser, A. K., Main, M. R., Winterbourn, M. J. (1990) Do organic and anthropogenic acidity have similar effects on aquatic fauna? *Oikos*, 33-38.

Cone, D. (2013) Personal Communication with Darryl Cone from the University of Canterbury Engineering Services, and part of the Okeover Stream restoration since it began. 21/03/2013.Christchurch.

Dushenkov, V., Pban, K., Motto, H., Raskin, I. (1995) Rhizofiltration: the use of plants to remove heavy metals from aqueous streams. *Environmental Science Technology* 29:1239–1245.

Environment Canterbury (2010) Waitaha Wai, Waterways of Christchurch. Environmental Canterbury, Regional Council and the Christchurch City Council, Booklet, 97 Pages. Retrieved online as of the 25/01/2013 from:

http://ecan.govt.nz/publications/General/waitaha-wai-waterways-of-christchurch-000610.pdf

Environment Canterbury (2010b) Chapter 3: Kaitiakitanga. Canterbury Waterways Management Strategy. Environment Canterbury. Retrived online on 20/12/2012. 50 pages.

Environment Canterbury (2011) Stormwater: Investigating stormwater and the role it plays in our waterways. Environment Canterbury. Educational Resource, 72 pages.

Environment Canterbury (2012) Environment Canterbury First Draft: Zone Implementation Programme (ZIP) for the Christchurch West Melton Zone. Environment Canterbury.

Ermens, R. (2007). Literature Review: Urban River Contaminants. Report No. U07/100, prepared by URS, for Environmental Canterbury, Christchurch, New Zealand. 84 pages.

Farrant, S. 2006, Contaminant characterisation of stormwater discharge into Okeover Stream and treatment recommendations. ENNR 429: Natural resource engineering project. A report submitted in partial fulfilment of the requirements for the BE (Hons) Degree in Natural Resource Engineering. University of Canterbury, Te Whare Wānanga o Waitaha. Christchurch, New Zealand.

Fukunaga, A., Anderson, M.J., and Webster-Brown, J.G. (2011) Assessing the nature of the combined effects of copper and zinc on estuarine infaunal communities. *Environmental Pollution* 159(1): 116-124.

Greig, H.S., Niyogi, D.K., Hogsden, K.L., Jellyman, P.G., Harding, J.S. (2010) Heavy metals: confounding factors in the response of New Zealand freshwater fish assemblages to natural and anthropogenic acidity. *Science of the Total Environment* 408: 3240–3250

Harmsworth, G. (2002) Coordinating Monitoring of New Zealand Wetlands, Phase 2, Goal 2: Maori environmental performance indicators for wetland condition and trend. Ministry for the Environment.66 pages.

Harding, J.S. (2005). Impacts of metals and mining on stream communities. In: Moore, T.A., Black, A., Centeno, A.A., Harding, J.S. and Trumm, D.A. (editors). *Metal contaminants in New Zealand*. Caxton Press, Christchurch, New Zealand.

Headley, T.R., Tanner, C.C. (2006) Application of Floating Wetlands for Enhanced Stormwater Treatment: A Review. Auckland Regional Council Report. 100 pages.

Hepburn, C.D., Jackson A. M., Vanderburg, P.H., Kainamu A., Flack, B. (2010) Ki Uta ki Tai: From the mountains to the sea. Holistic approaches to customary fisheries management. Proceedings of the 4th International Indigenous Conference on Traditional Knowledge: Kei muri i te kāpara he tangata, Recognizing, engaging understanding difference. P. 140-148.

Hewson, K.I., O'Brien, L.K., Barker, R.M., Weston, J.G. (2006) Chapter 14 Restoring the Waterways of the University of Canterbury, Christchurch, New Zealand. In: Sustainability in the Australian University Context. Environmental Education, Communication and Sustainability (Eds. Filho, W.L., and Carpenter, D.). Vol. 22. Peter Lang GmbH; Germany.

Hunt, S.M. (2011) A Comparison of the Performance of Contrasting Stormwater Treatment Systems, Ryelands Subdivision, Lincoln, Canterbury. A thesis submitted in partial fulfilment of the requirements for the Degree of Master of Applied Science at Lincoln University. Canterbury, New Zealand.

Landner, L., and Reuther, R. (2004) Metals in Society and in the Environmental: A critical review of current knowledge on fluxes, speciation, bioavailability and risk for adverse effects of copper, chromium, nickel and zinc. Environmental Pollution. Kluwer Academic Publishers, Dordrecht.

LeBlond, S.S.M-P. (2009) Examination of Metal Contamination within the UNESCO Designated Rideau River Waterway. A Masters of Science thesis submitted to the Department of Biology. Queen's University, Ontario, Canada.

Matunga, H. (2000). Urban Ecology, tangata whenua and the colonial city. In G.L. Stewart & M. E. Ignatieva (Eds.), Urban Biodiversity and Ecology as a Basis for Holistic Planning and Design (pp. 65-71). Christchurch: Lincoln University International Centre for Nature Conservation & Wickliffe Press.

McIntosh, A. (2007) Where to from here and how? Factors influencing ecosystem rehabilitation. Urban waterways forum Presentation 17 February 2007. University of Canterbury, Te Whare Wānanga o Waitaha. Christchurch, New Zealand.

Ministry for the Environment. 2005b. Wai Ora: Report of the Sustainable Water Programme of Action Consultation Hui. Wellington: Ministry for the Environment. 226 pp.

Morgan, T.K.K. (2007) Translating Values and Concepts into a Decision Making Framework: Application of the Mauri Model for Integrated Performance Indicator Assessment. Presentation at National Workshop for the Roundtable on Sustainable Forests, Forest Products Laboratory, Madison, Wisconsin.

O'Sullivan, A., Wicke, D., Cochrane, T. (2012). Heavy metal contamination in an urban stream fed by contaminated air-conditioning and stormwater discharges. *Environmental Science and Pollution Research*, 1-9.

Panelli, R., Tipa, G. (2009) Beyond foodscapes: Considering geographies of Indigenous well-being. *Health & Place*, 15: 455-465.

Pauling, C., Lenihan, T.M., Rupene, M., Tirikatene-Nash, N., Couch, R. (2007) State of the Takiwā, Te Āhuatanga o Te Ihutai. Cultural Health Assessment of the Avon-Heathcote Estuary and its Catchment. 72 pages.

Pauling, C., and Arnold, J. (2009) Chapter 8 Cultural Health of the Lake. In: Hughey, K.F.D., and Taylor K.J.W. (eds). Te Waihora/Lake Ellesmere: State of the Lake and Future Management. EOS Ecology, Christchurch. 150 pages.

Richard, J., and Taylor, M.J. (2002) A guide to restoring inanga habitat. Report for NIWA Science and Technology Series No. 50. Wellington, New Zealand. 31 pages.

Skinner, K., Wright, N., Porter-Goff, E. (2007) Mercury uptake and accumulation by four species of aquatic plants. Environmental Pollution 145 234e237

Stewart, M., Olsen, G., Phillips, N., Hickey, C. (2010) Contaminants in Kai – Arowhenua rohe. Part 1: Data Report. NIWA Client Report, 79 pages.

Suren, A and Elliot, S (2004). Effects of urbanisation on streams. In: Harding, J., Mosley, P., Pearson, C., Sorrell, B., (Eds.), Freshwaters of New Zealand. New Zealand Hydrological Society.

Taffs, E. 2007, Quantifying stormwater contaminants in water and sediment in the Okeover Stream, Christchurch. Natural resource engineering summer research project. University of Canterbury, Te Whare Wānanga o Waitaha. Christchurch, New Zealand.

Tau, T.M., Goodall, A., Palmer, D., Tau, R. (1990) Te Whakatau Kaupapa: Ngāi Tahu Resource Management Strategy for the Canterbury Region, Aoraki Press, Wellington, New Zealand. 78 pages.

Tau, T. (2000). Ngai Tahu – From 'better be dead and out of the way' to 'to be seen to belong'. In Cookson. J., Dunstall, G. (Eds.), Southern capital, Christchurch: towards a city biography 1850-2000. Christchurch, New Zealand: Canterbury University Press.

Te Rūnanga o Ngāi Tahu (2004) State of Takiwā, Cultural Monitoring and Reporting on the Health of our Environment. Scoping Document, 28 pages.

Thin, J. 2007, Water at the University of Canterbury: a brief historical overview. Social Science and Research Centre. Urban waterways forum Presentation 17 February 2007. University of Canterbury, Te Whare Wānanga o Waitaha. Christchurch, New Zealand.

Tipa, G., and Teirney, L. (2006a) A Cultural Health Index for Streams and Waterways: A tool for nationwide use. A report prepared for the Ministry for the Environment, Manatu Mō Te Taiao. 58 pages.

Tipa, G., and Teirney, L. (2006b) Using the Cultural Health Index: How to assess the health of streams and waterways. The Ministry for the Environment, Manatu Mō Te Taiao. 54 pages.

University of Canterbury (2012) Campus Master Plan. University of Canterbury, Te Whare Wānanga o Waitaha. Christchurch, New Zealand. http://www.canterbury.ac.nz/theuni/campus_plan/

Wang, G., Su, M.Y., Chen, Y.H., Lin, F.F., Luo, D., Gao, S.F. (2006) Transfer characteristics of cadmium and lead from soil to the edible parts of six vegetable species in southeastern China. *Environmental Pollution* 144, 127e135.

Wicke, D., Cochrane, T., O'Sullivan, A.D. (2010) Contaminant Sources, transport and fate in stormwater runoff in Christchurch, New Zealand. Auckland, New Zealand.: 17th Congress of the Asia and Pacific Division of the International Association of Hydraulic Engineering and Research incorporating the 7th International Urban and Watershed Management Conference, 21-24 Feb 2010. Proceedings of the 17th Congress of the Asia and Pacific Division of the International Association of Hydraulic Engineering and Research incorporating the 7th International Urban and Watershed Management Conference.

Williamson, R.B., and Morrisey, D. J. (2000) Stormwater Contamination of Urban Estuaries. 1. Predicting the Build-Up of Heavy Metals in Sediments. *Estuaries* 23(1): 56-66.

Zanders, J.M. (2005). Road Sediment: Characterisation and implications for the performance of vegetated strips treating road runoff. *Science of the Total Environment* 339(1-3): 41-47.

Zhang, H., Cui, B., Xiao, R., Zhao, H. (2010) Heavy metals in water, soils and plants in riparian wetlands in the Pearl River Estuary, South China. International Society for Environmental Information Sciences 2010 Annual Conference (ISEIS). *Procedia Environmental Sciences* 2:1344–1354

APPENDICES

Appendix A. Reported pH and metal concentrations (g/m³) in the Okeover stream and the West Coast streams.

Input	Site	Reference	Area	pH	Zn	Pb	Cu	Ni	Cd	Cr	Fe	Al	Mn
Stormwater	Okeover stream	Farrant (2006)	University/CBD 11-12/05/06	6.4 - 6.6	0.031	>0.0056	>0.0025	0.0017	<0.00005	0.003			
Stormwater	Okeover stream	Farrant (2006)	University/CBD		0.402	0.03-0.05	0.0203			0.085			
Stormwater	Okeover stream	Taff (2007)	University/CBD	6.5 - 6.7	0.521	0.0734	0.028-0.025						
Stormwater	Okeover stream	Ermens (2007)*	University/CBD		0.274	0.0173	0.0077						
Stormwater	Okeover stream	Ermens (2007)*	University/CBD		0.3	0.0194	0.0093						
Stormwater	Okeover stream	Ermens (2007)*	University/CBD		0.031	0.0018	0.0073						
Stormwater	Okeover stream	Ermens (2007)*	University/CBD		0.287	0.0324	0.0301						
Stormwater	Okeover stream	Ermens (2007)*	University carpark 1/03/07		0.116	0.0155	0.0054						
Stormwater	Okeover stream	Ermens (2007)*	University carpark 1/04/07		0.057	0.0062	0.0021						
Baseflow 2006	Okeover stream	O'Sullivan et al.(2012)	University/CBD		0.0078	0.00028	0.0068						
Baseflow 2009	Okeover stream	O'Sullivan et al.(2012)	University/CBD	6.1 - 6.8	0.0153	0.00165	0.0124						
Air-conditioning p	Okeover stream	O'Sullivan et al.(2012)	University/CBD		0.0124	0.00054	0.0088						
Stormflow	Okeover stream	O'Sullivan et al.(2012)	University/CBD		0.271	0.026	0.016						
Water quality	West Coast	Greig et al. (2010)	Mining stream water	3.1 - 8.1	0.17			0.035			2.23	7.29	0.58
Water quality	West Coast	Greig et al. (2010)	Naturally acidic stream wate	4.3 - 6.0	0.012			0.0006			0.29	0.52	0.007
Water quality	West Coast	Greig et al. (2010)	Circum-neutral stream water	6.2 - 7.6	0.0056			0.0006			0.15	0.11	0.0049

*Ermens (2007) is a literature review of compiled data from past studies across Chrsitchurch and Nationally.

Appendix B. Table of metal presence reported by local, national and international studies in freshwater waterways.

Brassica juncea	Indian mustard	International study	Dushenkov et al. (1995)	Cu, Cd, Cr, Ni, Pb, Zn
Brassica juncea	Indian mustard	International study	Turan & Esringü (2007)	Cd, Cu, Pb, Zn
**Rorippa nasturtium-aquaticum* (L.)	Great/green/true watercress	Lincoln, NZ	Hunt (2011)	As, Cd, Cu, Pb, Zn, P
Ipomoea aquatica	Water spinach	International study	Wang et al. (2006)	Cd, Pb
Pistia stratiotes	Water lettuce	International study	Skinner et al. (2007)	Hg
Eichornia crassipes	Water hyacinth	International study	Skinner et al. (2007)	Hg
Scirpus tabernaemontani	Zebra rush	International study	Skinner et al. (2007)	Hg
Colocascia esculenta	Taro	International study	Skinner et al. (2007)	Hg
Ceratophyllum demersum	Hornwort / coontail	International study	Park et al. (2011)	As, Pb, Cr, Cu, Zn
Hydrilla certicillata		International study	Park et al. (2011)	As, Pb, Cr, Cu, Zn
Hydrocharis dubia		International study	Park et al. (2011)	As, Pb, Cr, Cu, Zn
Salvinia natans		International study	Park et al. (2011)	As, Pb, Cr, Cu, Zn
Myriophyllum aquaticum	Parrot's feather/thread of life	Australian study	Cardwell et al. (2002)	Cd, Cu, Pb, Zn
Typha spp.	Cumbungi	Australian study	Cardwell et al. (2002)	Cd, Cu, Pb, Zn
Persicaria spp.	Knotweeds/willow smartweed	Australian study	Cardwell et al. (2002)	Cu, Zn, Pb
Colocascia esculenta	Taro, Elephant's Ear	Australian study	Cardwell et al. (2002)	Cd, Cu, Pb, Zn
Cyperus eragrostis	Umbrella sedge	Australian study	Cardwell et al. (2002)	Cd, Cu, Pb, Zn
Eleocharis equisitina	Spike rush	Australian study	Cardwell et al. (2002)	Cd, Cu, Pb, Zn
Nymphaea violacea	Waterlily	Australian study	Cardwell et al. (2002)	Cd, Cu, Pb, Zn
Anguilla australia & A.dieffenbachii	Short and long fin eel	Arowhenua rohe, NZ	Stewart et al. (2010)	As, Cr, Cu, Pb, Ni, Zn, Cd Cu, Pb, Hg, Zn
Salmo trutta	Brown Trout	Arowhenua rohe, NZ	Stewart et al. (2010)	As, Cu, Hg, Zn
Rhombosolea retiaria	Pātiki, black flounder	Arowhenua rohe, NZ	Stewart et al. (2010)	As, Cu, Hg, Zn
Nasturtium officinale	Watercress	Arowhenua rohe, NZ	Stewart et al. (2010)	As, Cu, Cr, Zn, Ni, Cd
Juncus sp.	Rushes	Kaiapoi, Chch, NZ	Chagué-goff (2004)	Cu, Zn, Pb
Lythrum hyssopifolia	Lesser loostrife	Kaiapoi, Chch, NZ	Chagué-goff (2004)	Cu, Zn, Pb