Appendix 1: Glossary

Glossary of Maaori terms		
Te Reo Maaori term	**English terminology**	**Scientific term**
A		
Ariari	Board used during whitebaiting	
Aroha	Show sincerity and mutual respect	
Atua	Ancestor with continuing influence, god, supernatural being, deity	
Aua	Yellow eyed mullet	*Aldrichetta forsteri*
Awa	River, stream, creek	
H		
Hani-a-te-waewae-i-kimi-atu	The male element	
Hapuu	Sub-tribe	
Harakeke	Flax	*Phormium tenax*
Hui	Assemble, assembly, meeting, gathering	
I		
Iinanga	Common galaxias, juveniles are a component of the whitebait catch	*Galaxias maculatus*
Iwi	Tribe, nation, people, society	
K		
Kaaeo	Freshwater mussel	*Hyridella menziesi*
Kaainga	Home, abode, dwelling	
Kaakahi	Freshwater mussel	*Hyridella menziesi*
Kahikatea	White pine	*Dacrycarpus dacrydioides*
Kai	Eat, food, dine	
Kai awa	Food from the river	
Kaihoe	Paddler, rower	
Kaitiaki	Guardian, caretaker, manager, trustee	
Kaitiakitanga	Guardianship	
Kanohi kitea	The `seen face'	
Karakia	Incantation, prayer, chant	
Kaumatua	Elder (singular), not gender specific	
Kaumaatua	Elders (plural), not gender specific	
Kaupapa	Strategy, theme, philosophy	
Kawa	Ceremonial rituals, protocol	
Kiingitanga	The King Movement - a movement which developed in the 1850s, established to stop the loss of land and promote Maaori authority, to maintain law and order, and to promote traditional values and culture	
Koikoi	Species of fern	*Blechnum minus*
Kooaro	Climbing galaxias, juveniles are a	*Galaxias brevipinnis*

	component of the whitebait catch	
Koohanga	Nest, nursery	
Kookopu	Galaxiids (including banded, giant, and short jaw kookopu), juveniles are a component of the whitebait catch	
Koorero	Speech, narrative, story, news, account, discussion, conversation, discourse	
Kooura	Freshwater crayfish	*Paranephrops spp.*
Koowhai	Trees in the genus *Sophora* native to New Zealand	*Sophora spp.*
Korimako	Bellbird	*Anthornis melanura*
Koroneihana	Coronation - the year's biggest gathering of followers of the Kiingitanga, celebrating the anniversary of the anointing of the King (or Queen)	
Korowai	Cloak	
Kuia	Female elder	
Kura	School, education, learning, gathering. (Kura kaupapa are schools which operate under Maaori custom, using Maaori as the medium of instruction)	
Kuta	Great spike rush, bamboo spike-sedge	*Eleocharis sphacelata*
M		
Maahaki	Exercise humility	
Maanuka	Tea tree	*Leptospermum scoparium*
Maaori	Indigenous person of *Aotearoa*/ New Zealand	
Maatauranga Maaori	Maaori knowledge - the body of knowledge originating from Maaori ancestors, including the Maaori world view and perspectives, Maaori creativity and cultural practices	
Mahinga kai	Food gathering areas	
Maimai aroha	Lament, mourn /expression of affection shown to the person who has passed away	
Mana	Prestige, authority, control, power, influence, status, spiritual power, charisma - mana is a supernatural force in a person, place or object	
Mana o Te Awa	Seeks respect for: • He tupuna awa (ancestral river) • Whakapapa and unity of the River tribes • The unique relationship of the people with the River • Responsibilities of Waikato-Tainui and other river iwi to protect the mana of the River	

Mana Whakahaere	Refers to the authority that Waikato-Tainui and other river iwi have established in respect of the River, over many generations	
Manaaki tangata	practise reciprocity and generosity	
Manaakitanga	Hospitality (ability of hosts to care for their visitors), kindness, blessing	
Manuhiri	Visitor, guest	
Marae	Sacred meeting place, courtyard in front of the wharenui (meeting house)	
Mate Maaori	Spiritual sickness (from a Maaori worldview)	
Mauri	Life principal/force, entity	
Mokopuna	Grandchild, descendant	
N		
Ngaa Aitanga a Tiki	Descendents of Tiki, human beings	
Ngaawhaa	Geothermal hot pools, boiling spring, volcanic activity, boiling mud pool, fumarole, sulphur water, geyser	
P		
Paa	Traditional settlement	
Paa tuna	Eel weirs	
Paanui	Announcement, advertise	
Paatiki	Flounder	*Rhombosolea plebeia*
Piiharau	Lamprey	*Geotria australis*
Poorohe	Common smelt	*Retropinna retropinna*
Poukai	Annual visitation to marae aligned to the Kiingitanga – to contribute and discuss important tribal affairs, to feed the widowed, bereaved and the destitute	
Puhi	Variety of tuna, Waikato-Tainui term	
R		
Raahui	To put in place a temporary ritual prohibition, closed season, ban, reserve - traditionally a raahui was placed on an area, resource or stretch of water as a conservation measure or as a means of social and political control for a variety of reasons which can be grouped into three main categories: pollution by tapu, conservation and politics	
Raaranga	Weaving arts	
Rama kooura	Spotlighting - to catch kooura by torchlight	
Rangatahi	Youth, younger generation	
Rangatira	Chief (male or female), leader, proprietor - qualities of a leader is a	

	concern for the integrity and prosperity of the people, the land, the language and other cultural treasures and an assertive and sustained response to outside forces that may threaten these	
Rangatiratanga	Sovereignty, chieftainship, leadership, right to exercise authority, chiefly autonomy, self-determination, self-management, ability to lead, ownership	
Raupatu	Invasion and war by land and by the Waikato River, and subsequent confiscation of Waikato lands	
Raupoo	Bullrush, cat’s-tail	*Typha orientalis*
Riiringi	To pour, sprinkle (water)	
Rohe	Tribal boundary, district, region, territory, area, border (of land)	
Rongoaa	Remedy, medicine, drug, cure, medication, treatment, solution (to a problem), tonic	
Ruru	Morepork	*Ninox novaeseelandiae*
T		
Tamariki	Children	
Taangata whenua	People of the land, locals, host, resident, people born of the whenua, i.e. of the placenta and of the land where the people's ancestors have lived and where their placenta are buried	
Tangi	Mourn, funeral	
Tangihanga	Weeping, crying, funeral, rites for the dead	
Taniwha	Metaphor for a chief, a monster good and bad that resides in water, taniwha take many forms from logs to reptiles and whales and often live in lakes, rivers or the sea. They are often regarded as guardians by the people who live in their territory/Also can be an area to be aware of danger/kia tuupato – see tapu	
Taonga	Goods, possessions, effects, treasure, gifts, something prized	
Taonga tuku iho	Treasure handed down, similar to inheritance	
Tapu	Restriction - a supernatural condition. A person, place or thing is dedicated to an atua and is thus removed from the sphere of the profane and put into the sphere of the sacred. It is untouchable, no longer to be put to common use.	

	Tapu was used as a way to control how people behaved towards each other and the environment, placing restrictions upon society to ensure that society flourished	
Tau kooura	Te Arawa method of catching kooura	
Te Ira Atua	God essence	
Te Reo Maaori	Maaori language	
Te Ture Whaimana	The Vision and Strategy for the Waikato River	
Teina (singular), teeina (plural)	Younger brother(s) (of a male), younger sister(s) (of a female), junior relative(s)	
Tikanga	Correct procedure, custom, habit, lore, method, manner, rule, way, code, meaning, plan, practice, convention	
Toetoe	Species of tall grasses native to New Zealand	*Cortaderia spp.*
Tohu	Sign, identify, mark, symbol, indicate	
Tootara	Species of podocarp tree endemic to New Zealand	*Podacarpus totara*
Tuakana (singular), Tuaakana (plural)	Elder brother (of a male), elder sister (of a female), senior relative	
Tuna	Freshwater eel	*Anguilla dieffenbachii (longfin); Anguilla australis (shortfin)*
Tupuna (singular), tuupuna (plural)	Ancestor(s)	
Awa tupuna	Ancestral river	
Tuuii	Parson bird	*Prosthemadera novaeseelandiae*
Tuurangawaewae	A place to stand, home ground, place where one has rights of residence and belonging through kinship and whakapapa	
Tuupatotanga	Demonstrate caution	
U		
Urupaa	Cemetery, burial place, graveyard	
W		
Waahi tapu	Shrine, sanctuary, sacred area/place	
Waananga	Place of learning	
Wai	Water	
Wairua	Spirit, soul	
Waka	Canoe	
Waka ama	Outrigger canoe	
Waka taua	War canoe	
Waka tiiwai	Dugout canoe with attached sides	
Whaanau	Extended family, family group, to be born	

Whakairo	Carving	
Whakamaa	Be ashamed, shy, bashful, embarrassed	
Whakapapa	Genealogy, genealogical table, lineage, descent, ancestry	
Whakawhanaungatanga	Honour relationships	
Whanaungatanga	Relationship, kinship, sense of family connection - a relationship through shared experiences and working together which provides people with a sense of belonging. It develops as a result of kinship rights and obligations, which also serve to strengthen each member of the whaanau. It also extends to others to whom one develops a close familial, friendship or reciprocal relationship	
Whareweku	Bracken fern bundles, component of the tau kooura	
Whenua	Land, country, earth, placenta, afterbirth	

Appendix 2: Restoration Case Studies

1. Introduction

Over the past 30 years there has been a substantial increase in river restoration efforts worldwide (Alexander and Allan, 2007; Giller, 2005) and this has been accompanied by advances in the science of river restoration (Ormerod, 2004; Roni et al., 2002). There are now a number of useful reviews of restoration which help to identify what makes for successful restoration outcomes and commonly occurring problems. However, despite the amount of restoration activity occurring there are few clear success stories and the scientific basis for restoration is incomplete (Brooks and Lake, 2007).

Restoration in the United States

In the United States there has been an exponential increase in river restoration projects since the 1990s and restoration now plays an important part in environmental management. The National River Restoration Science Synthesis (NRRSS) project has compiled a database of over 37,000 restoration projects being carried out mainly in the United States (Bernhardt et al., 2005a; Bernhardt et al., 2005b). These range in size from small community-based activities reliant on voluntary and 'in-kind' support through to large restoration projects which have been running for decades and involve expenditure of billions of dollars. The picture that emerges is that a comprehensive analysis of restoration progress in the United States is not possible because of lack of records and piecemeal information. Of the 37,000 projects reviewed only 10 percent indicated that monitoring of progress or effectiveness was being carried out, although more expensive projects of the order of about US$1 million were likely to be monitored. This lack of monitoring or sufficient recording of project objectives, budgets or efficacy means that opportunities to learn from project successes and failures are being lost.

Restoration in Europe

In Europe, waterways and lakes have suffered from various forms of control, manipulation and pollution for the past 6,000 years so that there are now few rivers with natural flows and that are in a pristine condition (Nienhuis and Leuven, 2001). In Western Europe eutrophication from intensive agriculture and farming is a particular problem (Gulati and van Donk, 2002). The River Thames in Britain is one of the first well documented cases of successful restoration. The Thames had become seriously polluted by the early 1800s. Restoration started in the 1960s and largely through the building of sewage treatment plants the fish fauna of the river underwent a remarkable recovery (Gameson and Wheeler, 1977). There are now numerous cases of restoration being undertaken throughout Europe (e.g., see reviews in van Andel and Aronson, 2006; Nienhuis and Gulati, 2002). However, river restoration efforts in Europe are often complicated and compromised, especially for the large rivers because they flow through several countries (e.g., Weiring et al., 2010), and where flood protection and transport are of over-riding priority to restoration (e.g., Buijse et al., 2002).

Restoration in Australia

In Australia the construction of weirs, floodplain levees, dams and inter- and intra-catchment water transfer schemes have had a major impact on natural river systems. Flow regulation affects all the major Australian rivers and such regulation is acknowledged as a major cause of deterioration in many Australian river and floodplain ecosystems (Arthington and Pusey, 2003). There is now a national commitment to ecologically sustainable development and water reform, including restoration.

Brooks and Lake (2007) have collated and synthesized data on restoration projects in Victoria, Australia. Most of the 2,247 projects reviewed focused on riparian management including fencing, off-river watering points (to keep stock out of the riparian zone), native plant revegetation, weed management and willow removal. The rest mainly included bank stabilisation, habitat improvement and channel reconfiguration. Although financial information is often missing, it appears that a conservative estimate of total expenditure (not accounting for 'in-kind' and volunteer support) is that AU$131 million has been spent in Victoria on river restoration over the 1999-2001 period, or AU$44 million per year. Riparian management was the least expensive activity whereas projects involving stormwater management were the most expensive. In rural areas, riparian restoration is seen as an effective way to improve water quality by reducing sediment and nutrient inputs, stabilising riverbanks and limiting channel incision. As found in the United States, records of monitoring are often scarce or incomplete. Of the 2,247 Victorian cases examined, only 14 percent appeared to include monitoring or evaluation but information was inadequate for determining whether monitoring was being carried out to check that construction projects remained intact and that planted vegetation had survived. It was also not clear from the information recorded if monitoring data was used to evaluate the success of the project in achieving the restoration goals. Opportunities to use experience gained from past river restoration is limited. Another problem that has occurred is that organisational restructuring and poor data management have resulted in data and historical information relating to restoration projects being lost.

Restoration in New Zealand

Over the last 20 years there have been increasing attempts at restoration of New Zealand freshwater ecosystems (Quinn, 2009) and guidelines for restoration of aquatic habitats have been published (e.g., Collier, 1994; Rowe, 2004; Sorrell et al., 2004; Suren et al., 2004). Quinn (2009) summarised the range of restoration activities occurring in New Zealand, from individual landowners fencing and replanting along riparian zones through to nationally significant projects involving Fonterra and the government (Dairying and Clean Streams Accord), and regional coalitions between Maaori and regional and central government, and multi-million dollar budgets (e.g., Lake Taupoo $81.5 million and Rotorua/Te Arawa lakes $144 million). Stream and lake restoration case studies are being documented, and show progress towards many aspirations, on dairy (e.g., Wilcock et al., 2007; 2009) and drystock farms (Dodd et al., 2008 a,b,c; Quinn et al., 2007; 2009). Monitoring of intensive action to restore Lake Okaro has also shown significant benefits since 2003 (e.g., Paul et al., 2008; Özkundakci et al., 2009; Gibbs and Özkundakci, 2010). There are active research programmes on aquatic restoration within New Zealand Crown Research Institutes (CRIs), universities[1] and non-government organisations (NGOs[2]) and there is considerable collaboration between these organisations and with stakeholders.

Restoration and indigenous communities

Worldwide there are now many river restoration initiatives focused on the values of indigenous communities and also benefiting from the input of Traditional Ecological Knowledge (TEK). There are numerous websites and on-line resources available which focus on restoration from the perspective of indigenous peoples.

The **Indigenous Peoples' Restoration Network (IPRN)[3]** operates under the auspices of the Society for Ecological Restoration International[4]. The network's mission is:

- *"to support native and tribal communities in need of technical assistance for environmental restoration and cultural rehabilitation; and*
- *"to assist leaders and practitioners in their efforts to apply traditional ecological knowledge within their own vision of political, economic and cultural sovereignty."*

Their website provides many useful links to databases, resources, references and indigenous groups and organisations worldwide, including New Zealand, Australia and the Pacific Rim.

In the United States, the **American Indian Environmental Office (AIEO)[5]** coordinates the United States Environmental Protection Agency (USEPA) environmental protection efforts in Indian Country, with a special emphasis on building tribal capacity to administer their own environmental programs.[6] The American Indian Tribal

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[1] http://www.niwa.co.nz/our-science/freshwater/research-projects/all/restoration-of-aquatic-ecosystems and http://www.lernz.co.nz/index.html
[2] http://www.landcare.org.nz/regional-focus/central-north-island/waikato-lakes-catchments/
[3] Contact with IPRN has been established by Dr Gail Tipa, g.tipa@xtra.co.nz, ph 64 3 4894534
[4] http://www.ser.org/iprn/default.asp
[5] Contact with AIEO has been established by Dr Gail Tipa, g.tipa@xtra.co.nz, ph 64 3 4894534
[6] http://www.healthfinder.gov/orgs/HR3413.htm

Environmental Portal provides specific details relating to environmental policies, practices and laws.[7]

Restoration resources and support

In addition to the resources and networks being developed by indigenous groups, there are now worldwide initiatives to support and encourage river restoration. The following international centres aim to share technical knowledge and resources on river restoration:

Pacific
Australian River Restoration Centre (ARRC)

Asia
Asian River Restoration Network (ARRN)
Japan River Restoration Network (JRRN)

Europe
European Centre for River Restoration (ECRR)
The River Restoration Centre (UK) (RRC)
Danish Centre for River Restoration (Dansk Center for Vandløbsrestaurering – DCVR)
Netherlands Centre for River Studies (NCR)
Italian Centre for River Restoration (Centro Italiano per la Riqualificazione Fluviale – CIRF)

North America
River Restoration Northwest

Project WET[8] is a non-profit organisation which aims to support and educate children, parents, teachers and the wider community on water education.[9] Project WET operates worldwide and achieves its aims through training workshops, organising community events and festivals, and building international networks.

The Queensland-based **International WaterForum** is a joint venture between the International WaterCentre, the International Riverfoundation, the University of Queensland, Griffith University, Queensland Government and Brisbane City Council.[10] Their aim is to improve the business of water and river management by facilitating opportunities for education, professional development, knowledge sharing, networking and recognition of excellence within water and river management. The International

[7] http://www.epa.gov/tribalportal/trprograms/env-programs.htm
[8] Contact with Project WET has been established by Dr Gail Tipa, g.tipa@xtra.co.nz, ph 64 3 4894534
[9] http://www.projectwet.org
[10] http://www.watercentre.org/news/international-waterforum

WaterForum is also responsible for organising the **International Riversymposium**, a conference that focuses on water and river management. The 13th International Riversymposium is scheduled for 11-14th October 2010, in Perth.[11]

Case studies

There are numerous documented cases of river restoration worldwide. Many of these are of little direct relevance to the Waikato River because of differences in climate, hydrology and ecology. The following selection of case studies has been chosen because they provide lessons that could benefit restoration of the Waikato River. They have been chosen because they are good examples of:

- Approaches that can be taken (e.g., Glen Canyon, Columbia River Basin, Willamette Basin, South East Queensland).
- The complexity and expense of restoration projects (e.g., Colombia River Basin, Willamette Basin, Murray River, South East Queensland).
- Restoration of traditional fisheries, important to indigenous communities (e.g., Colombia River Basin).
- Engagement with indigenous communities as part of the restoration process (e.g., Colombia River Basin, Willamette Basin, Murray River).
- Community involvement (e.g., South East Queensland).
- Mitigating the impact of hydro dam operation (e.g., Glen Canyon).
- Regional significance (e.g., Murray River, South East Queensland).

Glen Canyon

The Glen Canyon dam case is an example of where it is recognised that science cannot provide certainty of a desired outcome, and with collaborative input from the community and stakeholders a Collaborative Adaptive Management (CAM) approach was taken (NRC, 1999). The Glen Canyon dam is located on the Colorado River just south of the Arizona-Utah border. The Colorado River then passes through Marble Canyon before entering the Grand Canyon National Park and flowing into Lake Mead, formed by the Hoover dam. The area is home to several American Indian tribes and as well as its cultural importance it has exceptional ecosystem values and is a World Heritage Site. The Glen Canyon dam and its operations have profoundly altered the hydrology and temperature regime of the river with significant effects on the Colorado River ecosystem and the surrounding desert country.

The Glen Canyon dam Adaptive Management Program (AMP) was established in 1997 with the aim of co-ordinating research and monitoring of the downstream ecosystem

[11] http://www.riversymposium.com/

and resources. A Federal Advisory Committee which includes input from stakeholders has responsibility for facilitating the program and making recommendations on actions to improve the downstream ecosystem and resources. Scientific experimentation is integrated into the management actions.

Although the Glen Canyon case had been promoted as an example of the successful application of CAM, it has also been severely criticised by Susskind et al., (2010). They maintain that the programme has failed to increase the understanding of stakeholders and has not resulted in them making informed management recommendations. The result is that it has not stabilised or improved the river ecosystem, despite the expenditure of several millions of dollars over the past 13 years. Susskind et al., (2010) maintain that this failure has arisen because of fundamental flaws in the set-up of the Adaptive Management Program, with only partial stakeholder representation, confused and uncertain decision-making authority and lack of responsibility, and an ineffective dispute resolution process.

Columbia River Basin

The 2,000 kilometres long Columbia River is the largest river in the Pacific Northwest. Its catchment lies within seven United States states and British Columbia, Canada. The river's ecology and resources make a significant contribution to the economy of the Pacific Northwest region. About eight million people live within the catchment basin and the river has 14 hydropower dams. Traditionally, the Columbia River and its tributaries supported the largest salmon fishery in the world. With the extensive development of the river catchment there has been substantial habitat loss and degradation and contamination by chemical pollutants now pose a risk to fish, wildlife and humans[12].

Some of the local Indian tribes regard salmon to be part of their spiritual and cultural identity, and fishing is still the preferred livelihood of many tribal members. Treaties between individual tribes and the federal government acknowledge the importance of salmon and steelhead, and guarantee fishing rights. To mitigate the effects that hydro dams have on fish migration, hatcheries now operate along the river. In 1977 four Indian tribes with treaty fishing rights on the river formed the Columbia River Inter-Tribal Fish Commission (CRITFC)[13] to coordinate their activities in fisheries management and restoration. They have also developed a holistic salmon management plan that aims to increase survival at each stage of the fish's anadromous[14] life cycle.

[12] http://www.cleanwaternetwork.org/sites/default/files/Columbia%20River%20One-Pager%20final.pdf
[13] http://www.critfc.org/
[14] Fish that migrate from the sea up rivers to spawn.

Restoration in the lower river is co-ordinated by the Lower Columbia River Estuary Partnership (LCREP)[15]. This Partnership integrates the restoration activities of multiple stakeholders from 28 cities, nine counties and the states of Oregon and Washington. They also have responsibility for implementing the Comprehensive Conservation and Management Plan for the Lower Columbia River.

The United States Senate is currently considering legislation that would authorise the United States Environmental Protection Agency to provide clean-up technical assistance and help to river stakeholders (including state and local agencies, tribal governments, industry, landowners and environmental groups). The legislation would also authorise a budget of US$40 million annually.

Willamette Basin

The Willamette Basin restoration programme has many parallels with the Waikato River restoration proposal. The Willamette River is 301 kilometres long and is a major tributary of the Columbia River, draining a densely populated region of the Pacific Northwest of the United States. The river and its tributaries form a basin called the Willamette Valley.

The area has been home to several American Indian tribes for at least 10,000 years, many having a close association with the river and depending on it for food, clothing, tools, transportation and spiritual sustenance. Widespread development and increases in population over the past few hundred years has resulted in the river becoming seriously polluted. Fisheries have declined and the water was unsafe for drinking or swimming.

Faced with continuing catchment basin development and a growing population the Willamette Restoration Initiative (WRI) was charged with developing the Willamette Restoration Strategy (WRI, 2001). The strategy sets out to:

- protect and restore fish and wildlife habitat;
- enhance populations of other declining native species;
- improve water quality; and
- improve management of floodplains.

The Willamette Restoration Initiative's activities are controlled by a board of directors, selected to represent the various interests and perspectives of the wider community, including those of local Indian tribes. The board has representatives of local government, utilities, tribes, academia, watershed groups, soil and water conservation districts, agriculture, forestry, environmental groups, and state and federal government.

[15] http://www.lcrep.org/about-us

The strategy was developed through a collaborative process and represents a holistic, integrated action plan. It incorporates existing restoration initiatives and builds on the existing knowledge of the system. It incorporates a variety of restoration approaches and by recognising the multiple and diverse values held by stakeholders, it attempts to balance the goals of a healthy environment, a high quality of life and a strong economy.

The strategy has identified 27 critical actions which fall into four restoration focus areas of:

- clean water;
- water quantity;
- habitats and hydrologic processes; and
- institutions and policies.

The strategy provides ways to measure restoration progress and to determine if the critical actions are achieving the restoration outcomes intended. Importantly, although the strategy provides a foundation for action, it is recognised that a flexible approach is needed and that there needs to be continuous assessment and revision to incorporate improved understanding and possibly changing restoration needs.

An interesting approach taken as part of the Willamette Basin restoration has been the use of alternative futures analysis (Baker et al., 2004). This involved modelling three alternative scenarios which captured future landscapes for the year 2050, based on different development options. The Plan Trend 2050 scenario assumed that current policies and trends continue. The Development 2050 scenario represented a loosening of current policies and a market-driven approach. The Conservation 2050 scenario assumed that ecosystem protection and restoration were accorded higher priority, although still within the bounds of what stakeholders considered realistic. The modeling results have been used to guide the basin-wide restoration strategy.

Restoration of the Willamette basin is recognised as being extremely complicated and requiring long-term commitment. Recent estimates just for restoration of streamside vegetation and streamside habitat throughout the Willamette basin ranged from US$593 million to US$1.2 billion (Michie, 2010).

Murray River

Restoration of the Murray River is Australia's largest river restoration project and is one of the largest restoration projects in the world. The Murray River is 2,756 kilometres long and runs through the three states of Victoria, New South Wales and South Australia. It is navigable for 1,986 kilometres, has four dams, 16 weirs and 15 navigable locks and provides domestic water supply for over 1.5 million households. Aboriginal occupation along the river goes back 40,000 years.

Flow regulation of the river was introduced to make the supply of water more reliable but it has significantly changed the river ecosystem and water quality has deteriorated. Native fish have declined in numbers and in range, vegetation has been affected and some areas of land have become affected by salt. In 2002, in response to this deterioration the Murray-Darling Basin Ministerial Council established the Living Murray program.[16]

The Australian, New South Wales, Victorian, South Australian and the Australian Capital Territory governments together made an initial commitment to the Living Murray Project of A$500 million over a five year period from 2004–05 and a further A$150 million over eight years. The Living Murray has established five programmes through which to direct restoration activities:

- **Water Recovery,** which addresses over-allocation of water resources in certain parts of the River Murray system and reclaims water for delivery to icon sites.
- **Water Application,** which ensures that water is delivered to achieve ecological benefits at the icon sites.
- **Environmental Works and Measures,** which aims at developing infrastructure which will help make the best use of water in the River Murray system.
- **Communication and Community Consultation,** which will ensure that local communities, key stakeholders and the public are able to receive information and offer their input.
- **Indigenous Partnerships,** which establishes a partnership programme so that the social, spiritual, cultural, environmental and economic interests of indigenous communities are considered.

South East Queensland[17]

The South East Queensland Healthy Waterways project has several useful parallels with the Waikato proposal especially in the terms of partnerships and collaboration, capacity building, monitoring and reporting. The project was initiated to address concerns about degrading water quality in the waters of Moreton Bay and inland waterways. Deteriorating water quality was linked to sewage discharges, and run-off and deposition of fine-grained sediments into Moreton Bay.[18]

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[16] http://www.thelivingmurray.mdbc.gov.au/index.html
[17] Contact with the SEQ Healthy Waterways project has been established by Dr Bruce Williamson, Diffuse Sources, bruce.williamson@diffusesources.com, ph 64 3 5484342
[18] http://www.healthywaterways.org/HealthyWaterways/Home.aspx

Fundamental to the project is the SEQ Healthy Waterways Partnership, a collaboration between government, industry, researchers and the community. In many ways, the approaches that are being taken are unique. The partnership includes representatives of seven state agencies, three national agencies, four state corporations, 11 local governments, 37 industries, nine research institutes and 40 community and environmental groups. Together they developed a restoration strategy which includes 12 action plans based on a combination of issue-based, enabling and area-based plans:

Issue -based action plans

- Point Source Pollution.
- Non-Urban Diffuse Source Pollution.
- Water Sensitive Urban Design.
- Protection and Conservation.
- Coastal Algal Blooms.

Enabling action plans

- Ecosystem Health Monitoring Program.
- Communication, Education and Motivation.
- Management Strategy Evaluation.

Area-based action plans

These focus on Moreton Bay and three separate catchments.

In total there are over 500 actions in the strategy that the partners have committed to implementing.

Another important aspect of this project is the Ecosystem Health Monitoring Program (EHMP). It is one of the most comprehensive marine, estuarine and freshwater monitoring programs in Australia and delivers a regional assessment, or Report Card, of the ambient ecosystem health for each of 19 catchments, 18 river estuaries and Moreton Bay.

Dam decommissioning and removal

With the large number of dams affecting river ecosystems in the United States, attention has turned to the option of their removal or ways of mitigating their impacts (e.g., Donnelly et al., 2005; O'Connor et al., 2008). The Federal Energy Regulatory Commission (FERC) has mandated changes in hydro dam operation to address environmental conditions including increased minimum flows, improved fish passage (both upstream and downstream), periodic high flows and riparian protection measures. Where mitigation cannot be achieved, dam removal is now seen as a legitimate option for consideration, especially where fish passage needs to be improved. Examples of successful dam removal have occurred in the United States, Canada, and Europe.

Although there are more than 75,000 listed dams in the United States (greater than 1.8 metres high), there are also an estimated two million smaller dams (Shuman, 1995). As such, the majority of dams that have been removed and are currently being considered for removal are relatively small, non-hydroelectric dams, particularly run-of-river structures. It is estimated that since 1912, 750 dams have been decommissioned with the rate increasing in recent years (O'Connor et al., 2008). It is important to note however that in the United States many of the structures being removed have reached the end of safe operational life or are obsolete. For example, there are many dams built in the 1800s to power textile mills which have now ceased to operate. The dams no longer serve any useful purpose and their removal is essential if the rivers they dam are to be restored to a natural state.

Lessons from past restoration attempts

Based on the many documented examples of restoration activities, there are some general observations and conclusions that can be made about river restoration, what needs to be considered, what makes for a successful outcome and what needs to be avoided:

1. Restoration is expensive – restoration projects on a catchment scale can typically require budgets of many millions of dollars.
2. Restoration is long-term – it may be several decades before significant restoration is achieved.
3. Collaboration is needed – restoration often requires participation, co-operation and collaboration from many parties including state and local government agencies, industry, universities, and representatives of indigenous groups, environmental care groups, sports groups and the wider community.
4. Build on existing initiatives – attempts should be made to build on existing restoration and environmental management and monitoring activities.
5. Define outcome – the overall outcome that is desired from restoration needs to be defined.
6. Set agreed objectives – it is important to have clearly defined and agreed restoration objectives that will meet the desired outcome, and all partners need to be committed to achieving these.
7. Use traditional knowledge and science – successful restoration relies on incorporating traditional knowledge (in this case maatauranga Maaori) and science. Also, scientific input must incorporate multi- and inter-disciplinary approaches (e.g., drawing on physical, chemical, geomorphological and ecological expertise).

8. Use science – use the extensive and growing body of restoration science to inform actions, monitoring and analysis.
9. Track expenditure and progress – records of expenditure and completion of specific restoration activities need to be recorded and audited.
10. Monitor – progress towards completing restoration activities, achievement of objectives and progress towards the overall outcome need to be monitored and the results publicised.
11. Learn from monitoring – monitoring results need to be analysed to determine the effectiveness of the actions undertaken.
12. Use adaptive management – because the outcome of specific restoration actions will not be reliably predictable there needs to be ongoing review of progress and if necessary modification and resetting of objectives and actions.
13. Outreach – there needs to be easy access to project information, objectives, planned actions, resources and monitoring results to all stakeholders and the community.
14. Plan for the future – restoration projects are typically of a long duration and this needs to be considered when setting up administrative and management systems. Staff turnover and operational restructuring need to be allowed for with robust systems able to survive in the long-term. Planning has to include information security, and backup and archiving. Standardised data systems and mandatory reporting are needed and changes in computing systems need to be considered so that information is not lost.

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Appendix 3: Te Ture Whaimana o Te Awa o Waikato – the Vision and Strategy for the Waikato River

The Guardians Establishment Committee presented Te Ture Whaimana o Te Awa o Waikato – the Vision and Strategy for restoring and protecting the health and wellbeing of the Waikato River to the Crown and Waikato-Tainui at a special hui (meeting) in June 2008. The Waikato River Independent Scoping Study reflects the vision, objectives and strategies identified in that document. They are set out below:

Vision for the Waikato River

Tooku awa koiora me oona pikonga he kura tangihia o te maataamuri

The river of life, each curve more beautiful than the last

Our vision is for a future where a healthy Waikato River sustains abundant life and prosperous communities who, in turn, are all responsible for restoring and protecting the health and wellbeing of the Waikato River, and all it embraces, for generations to come.

Objectives for the Waikato River

In order to realise the vision, the following objectives will be pursued:

a. The restoration and protection of the health and wellbeing of the Waikato River.

b. The restoration and protection of the relationship of Waikato-Tainui with the Waikato River, including their economic, social, cultural and spiritual relationships.

c. The restoration and protection of the relationship of Waikato River iwi according to their tikanga and kawa with the Waikato River, including their economic, social, cultural and spiritual relationships.

d. The restoration and protection of relationships of the Waikato Region's communities with the Waikato River, including their economic, social, cultural and spiritual relationships.

e. The integrated, holistic and co-ordinated approach to management of the natural, physical, cultural and historic resources of the Waikato River.

f. The adoption of a precautionary approach towards decisions that may result in significant adverse effects on the Waikato River and in particular those effects that threaten serious or irreversible damage to the Waikato River.

g. The recognition and avoidance of adverse cumulative effects, and potential cumulative effects, of activities undertaken both on the Waikato River and within its catchments on the health and wellbeing of the Waikato River.

h. The recognition that the Waikato River is degraded and should not be required to absorb further degradation as a result of human activities.

i. The protection and enhancement of significant sites, fisheries, flora and fauna.

j. The recognition that the strategic importance of the Waikato River to New Zealand's social, cultural, environmental and economic wellbeing requires the restoration and protection of health and wellbeing of the Waikato River.

k. The restoration of the water quality within the Waikato River so that it is safe for people to swim in and take food from over its entire length.

l. The promotion of improved access to the Waikato River to better enable sporting, recreational and cultural opportunities.

m. The application to the above of both maatauranga Maaori and latest available scientific methods.

Strategies for the Waikato River

To achieve the objectives, the following strategies will be followed:

1. Ensure that the highest level of recognition is given to the restoration and protection of the Waikato River.
2. Establish what the current health status of the Waikato River is by utilising maatauranga Maaori and latest available scientific methods.
3. Develop targets for improving the health and wellbeing of the Waikato River by utilising maatauranga Maaori and latest available scientific methods.
4. Develop and implement a programme of action to achieve the targets for improving the health and wellbeing of the Waikato River.
5. Develop and share local, national and international expertise, including indigenous expertise, on rivers and activities within their catchments that may be applied to the restoration and protection of the health and wellbeing of the Waikato River.
6. Recognise and protect waahi tapu and sites of significance to Waikato-Tainui and other river iwi (where they so decide) to promote their cultural, spiritual and historic relationship with the Waikato River.
7. Recognise and protect appropriate sites associated with the Waikato River that are of significance to the Waikato regional community.
8. Actively promote and foster public knowledge of the health and wellbeing of the Waikato River among all sectors of the Waikato regional community.
9. Encourage and foster a whole-of-river approach to the restoration and protection of the Waikato River, including the development, recognition and promotion of best practice methods for restoring and protecting the health and wellbeing of the Waikato River.
10. Establish new, and enhance existing, relationships between Waikato-Tainui, other Waikato River iwi (where they so decide) and stakeholders with an interest in advancing, restoring and protecting the health and wellbeing of the Waikato River.

11. Ensure that cumulative adverse effects on the Waikato River of activities are appropriately managed in statutory planning documents at the time of their review.
12. Ensure appropriate public access to the Waikato River while protecting and enhancing the health and wellbeing of the Waikato River.

A full copy of Te Ture Whaimana - the Vision and Strategy for the Waikato River can be found on the Guardians Establishment Committee website – www.river.org.nz.

Appendix 4: The Guardians Establishment Committee

4.1 The Guardians Establishment Committee – Terms of Reference

The Guardians Establishment Committee (GEC) was formed by the Agreement in Principle, signed by the Crown and Waikato-Tainui in 2007. The Guardians Establishment Committee was tasked with developing a vision and strategy to restore and protect the health and wellbeing of the Waikato River (see Appendix 3: Te Ture Whaimana – the Vision and Strategy for the Waikato River). Under the Committee's Terms of Reference they are also required to *"act as a governance group for the scoping study to identify rehabilitation priorities in relation to the Waikato River, identify the likely cost of priority activities, and provide useful background information to the establishment and operation of the Waikato River Clean-Up Trust[1]"*.

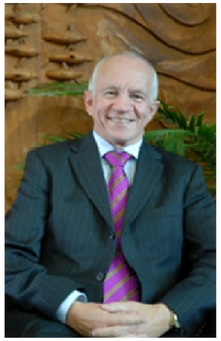
4.2 Membership of the Guardians Establishment Committee

The Guardians Establishment Committee comprises six appointees of the Crown, two appointees of Waikato-Tainui, and four appointees of representative bodies of other river iwi (Tuwharetoa, Maniapoto, Raukawa, and Te Arawa)[2]. They are:

Tukoroirangi Morgan
Guardians Establishment
Committee Co-Chairperson
(Waikato-Tainui)

Gordon Blake
Guardians Establishment
Committee Co-Chairperson
(Crown)

Linda Te Aho
(Waikato-Tainui)
Assoc. Dean, School of Law
University of Waikato



Bob Simcock
(Crown)
Mayor
Hamilton City Council

Dean Stebbing
(Tuwharetoa)
Advisor
Tuwharetoa Trust Board

Roger Pikia
(Te Arawa)
Board Member
Affiliate Te Arawa Iwi

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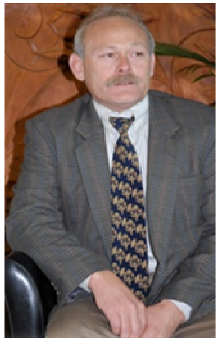
[1] Guardians Establishment Committee, Terms of Reference, October 2008, http://www.river.org.nz/file/Terms-of-Reference.pdf

[2] There were another four members of the Guardians Establishment Committee when it was originally formed. They were: Taipu Paki, Rangitiaho Mahuta, Clint Baddeley and Jenni Vernon.

Traci Houpapa
(Crown)
Principal
THS & Associates



Weo Maag
(Maniapoto)
Board Member
Maniapoto Trust Board

Andra Neeley
(Crown)
Councillor
Environment Waikato

Stephanie O'Sullivan
(Raukawa)
Environment Manager
Raukawa Trust Board

Alan Livingston
(Crown)
Mayor
Waipa District

Don Scarlet
(Crown)
Relationships Specialist
Mighty River Power

Appendix 5: Tuna

1. Introduction

The Waikato River supports New Zealand's largest tuna (freshwater eel) fishery (Ministry of Fisheries, 2009) but the decrease in both the quantity and quality of the tuna has been highlighted as a major concern by iwi (NIWA et al., 2009). Consultation with Maaori groups was carried out to cover the various regions of the Waikato River catchment from below Lake Taupoo down to the river mouth. This consultation is reported in NIWA et al., (2009) and indicated that tuna restoration was desired throughout the river, not only to provide a commercial income but also to provide a ready source of tuna for cultural events (hui (meeting), taangi (funeral)) and because the presence of a healthy tuna population in the river signifies a healthy river. A substantial decline in tuna taken for whaanau (family group), hapuu (sub-tribe) and personal use was also highlighted in an earlier survey carried out in the Ngati Maniapoto rohe (district) in 1997 (Watene-Rawiri, in press).

In this appendix, the Study team provide an analysis of the state of the tuna fishery in the Waikato River catchment, identify the main factors known to be responsible for the decline in this fishery, list the restorative actions that are known to be effective and table the indicative cost estimates needed to help prioritise these actions.

Historically puhi (variety of tuna, Waikato-Tainui term) tuna which consisted mainly of small downstream migrant (spawners) were intensely harvested with many paa (traditional settlement) tuna weirs constructed on the outlet of most lakes and in tributaries of the Waipa and Waikato Rivers. These fishing sites once provided an important and reliable source of food and the base of many an alliance, feud and battle (e.g., Ligar, 1846; Hamilton, 1908).

Today the fishery is largely undertaken on a commercial basis and is dominated by shortfin tuna (*Anguilla australis*) which, based on the data presented in Ministry of Fisheries (2009) and Beentjes (2008), comprise 70–75 percent of the catch[1]. The rest of the catch is composed of longfin tuna (*A. dieffenbachii*) with a very minor component of Australian longfin (spotted) tuna (*A. reinhardtii*). The estuary, Waikato River main stem and the Waipa River are the major source of commercially harvested tuna (Table 1). Management of the fishery is currently the responsibility of the Ministry of Fisheries who are bound, under the Fisheries Act 1996, to: "…*provide for the utilisation of fisheries resources while ensuring sustainability*".

[1] This current dominance by shortfins may not always have been the case as there is anecdotal evidence from commercial fishers that lowland virgin waters, like inland forested streams, were initially dominated by longfins.

Table 1: Mean annual commercial catch of tuna for habitats within the Waikato River 1991–1995 (from Beentjes and Chisnall, 1997)

	Mean catch per year (tonne)
Waikato River main stem	24.4
Waipa River	10.3
Waikato River estuary	7.5
Waikato River hydro lakes	6.2
Waikato River tributaries	3.3
Other Waikato Basin rivers	2.8
Whangamarino Swamp	0.4

North Island tuna were introduced into the Quota Management System on 1 October 2004. There are four stocks (tuna associated with a defined area) for each of the species in the North Island with the Waikato falling into area 21 (Figure 1). Total allowable catches (TAC) in each management area are set under Section 14 of the Fisheries Act 1996 and are regularly updated "*to ensure the best possible outcomes consistent with the purpose of the Act are produced*" (Ministry of Fisheries, 2009). In setting or varying any total allowable commercial catch (TACC) under Section 21 of the Act, the Minister of Fisheries has to take account of the TAC and allow for Maaori customary non-commercial fishing interest, as well as recreational interests and other mortality caused by fishing (Ministry of Fisheries, 2009). Current allowances for area 21 are given in Table 2.

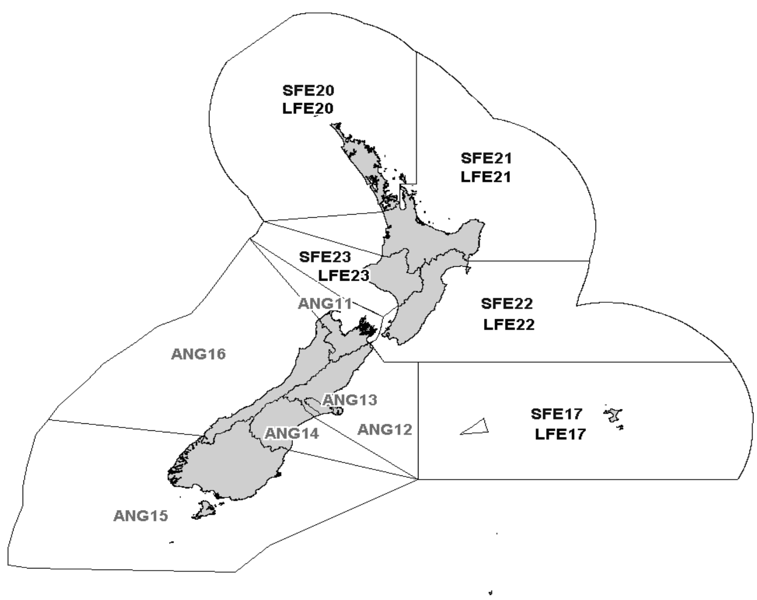


Figure 1: Quota management areas for shortfin (SFE) and longfin (LFE) tuna stocks in New Zealand as from 1 October 2004 (from Ministry of Fisheries, 2009)

Quota management areas are currently divided into 12 tuna statistical areas (ESA) which provide finer scale recording of the commercial catch. The Waikato catchment falls into ESA AD, which also includes the Mokau, Awakino, Marokopa and Raglan Harbour. Since 2003–04 the 12 ESAs have been further subdivided into 65 sub-areas (broadly equivalent to catchments) with 17 sub-areas in ESA AD (Beentjes, 2008).

Although there is robust recent information on the commercial tuna catch from the Waikato down to a fine scale, traditional and other catches remain unknown. For the purpose of this assessment it has been assumed that the present customary take equates to 25 percent of the present customary allowance of 40 tonnes (i.e., 10 tonnes) but is likely to be much less.

Table 2: Total allowable catch (TAC), customary, recreational, other sources of fishing related mortality and total allowable commercial catch (TACC) for tuna in quota management area 21 (Waikato/Bay of Plenty); (SFE = shortfin tuna, LFE = longfin tuna) (from Ministry of Fisheries, 2009).

Stock	TAC (tonne)	Customary allowance (tonne)	Recreational allowance (tonne)	Other sources of fishing-related mortality (tonne)	TACC (tonne)
SFE21	181	24	19	4	134
LFE21	60	16	10	2	32
Total	241	40	29	6	166

Commercial harvest of tuna in New Zealand began in the 1960s and peaked in the early 1970s at around 2,000 tonnes (Ministry of Fisheries' records, Figure 2). Catch record statistics from tuna return area AD, which includes the Waikato, have only been available since the 1983–84 fishing year (Figure 3). The records for area AD indicate that in 1984 the catch was 250 tonne. It declined to a low of 86 tonne in 1988–89 (Figure 3). From the early 1990s, commercial catches increased to a peak of 300 tonne by 1996. This short term increase appears to have been produced by an increase in the catch of longfins possibly because commercial fishers at the time targeted as yet un-fished waters. From 1997 onwards, catches gradually declined and are presently around 100 tonne per annum. As the annual catch for the Waikato River in 1980 was reported to be 400–450 tonnes (Todd, 1981), the statistical data for area AD indicate that there has been a decline in the commercial harvest of around 75 percent. However, these data do not apply just to the Waikato River catchment and do not include cultural and recreational harvests. Tuna catches can vary annually because of changes in management regimes, drought years and changes in the market. The data from commercial catches therefore need to be treated with some caution. This aside, the decline in annual commercial catches from 400-450 tonne in 1980 to less than 200 tonne since 2000 is of concern and supports the decline in the tuna fishery perceived by Maaori.

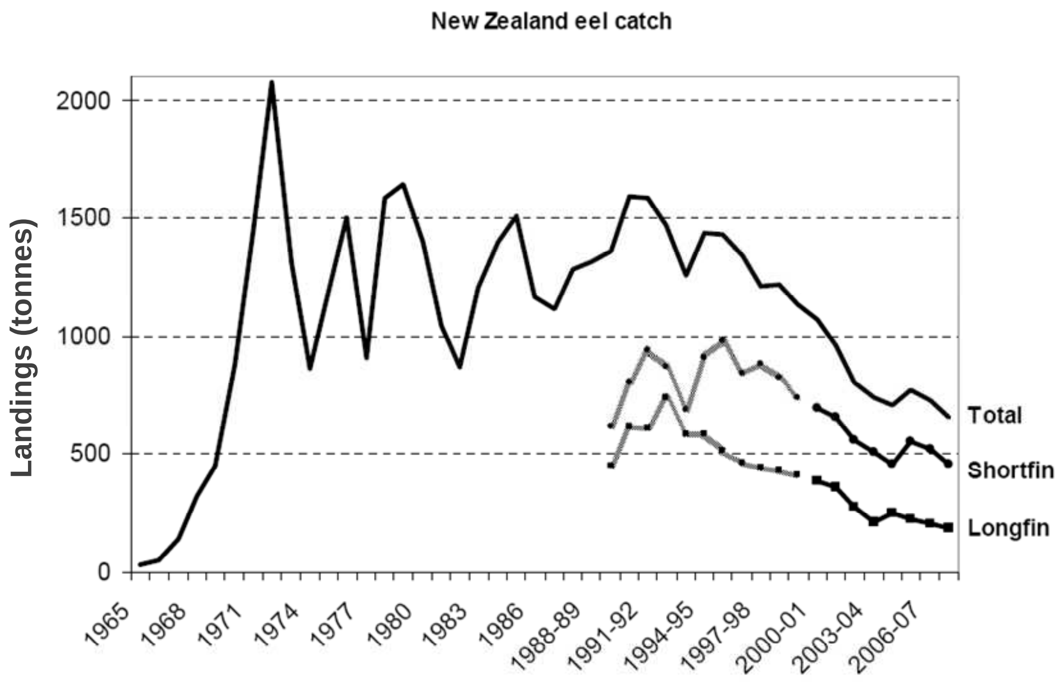


Figure 2: Total New Zealand tuna landings from 1965–2007/08. Estimated shortfin and longfin landings from 1989–90 to 2007–08 are also shown. The grey lines are for the period prior to the introduction of 'Tuna Catch Landing Return' forms providing data on catches and were generated by pro-rating the unidentified tuna catch by the available longfin/shortfin ratio (from Ministry of Fisheries, 2009).

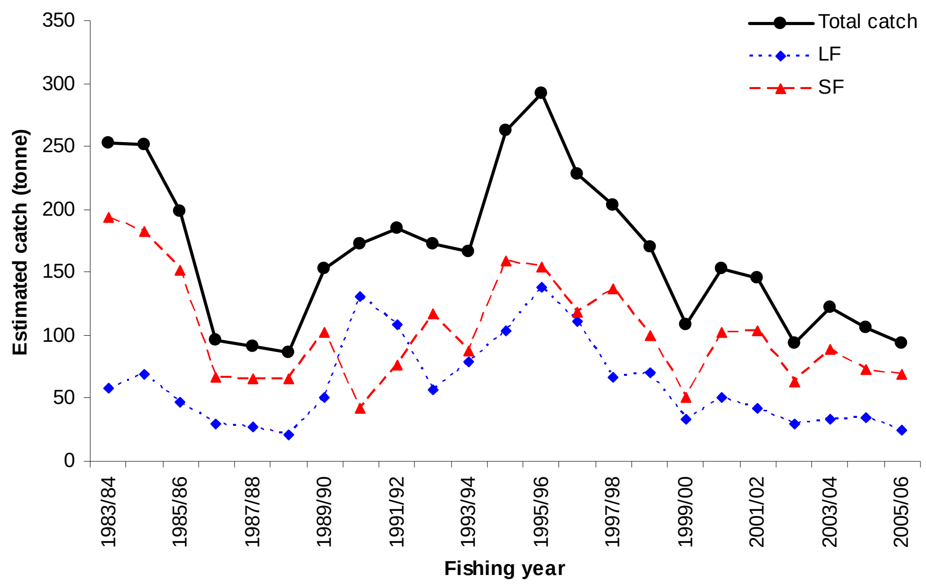


Figure 3: Total estimated catch of tuna, and the proportion of longfin (LF) and shortfin (SF) tuna in the commercial catch for the Waikato Basin (Statistical Area AD). Data for 1983–84 to 1989–90 from Jellyman (1993); data for 1990–91 to 1998–99 from Beentjes and Bull (2002). Official records after 2005–06 were not available at time of writing. Note: catches of longfin and shortfin tuna prior to the 2000–01 season are estimates as not all catches were identified to species.

As the total commercial catch declined so did the catch per unit effort (CPUE measured as the weight of tuna caught per net). For example, in Lake Waikare CPUE declined from 6.5 kilograms per net in 1977–78 to 1.37 kilograms per net in 1983–84. Overfishing was blamed for the decline (McLea, 1986) but this trend in declining catch was not only seen in the Waikato River, but countrywide (Jellyman, 1993). Apart from overfishing, continued loss and degradation of habitat[2] as well as loss of access (notably barriers created by flood protection structures), are likely contributors to the decline.

To compensate for losses of elvers (juvenile tuna) at the bases of hydro dams, and utilise upstream habitat that was denied to these small tuna, elver trap and transfer activities were implemented from the base of Karaapiro Dam to the upstream reservoirs in summer 1992–93 (Beentjes et al., 1997). All the Waikato reservoirs except Aratiatia are now seeded each summer under a permit issued by Ministry of Fisheries. Since monitoring began, catches of elvers have been relatively stable with around two million captured each year (Figure 4). In terms of the tuna life cycle, however, the records are very short and there is strong evidence that elver recruitment has declined markedly within the last 50 years[3].

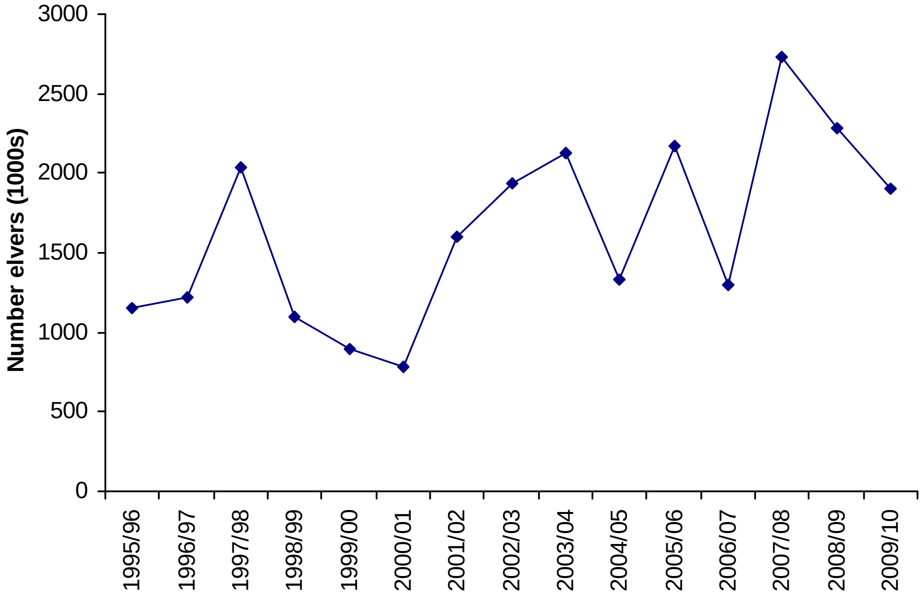


Figure 4: Total number of elvers captured at Karaapiro Dam 1995–96 to present. Note: although the trap and transfer programme began in 1993–94, comparable information is only available since 1995–96 (e.g., when the current trapping system was installed).

[2] According to MacGibbon (2001), only 25 percent of the original wetland remains in the Waikato.
[3] Cairns (1941) described a shoal of glass tuna 4.5 metres wide, 2.5 metres deep that took 8 hours to pass a point on the Waikato River. Such massive runs have not been seen since the 1970s.

A nationwide decline in recruitment is, therefore, another likely reason for the decline in the tuna population of the Waikato River. A recent review of glass eel recruitment to the lower Waikato River (Jellyman et al., 2009) found some evidence of an earlier arrival season today than 30 years ago, but also an overall reduction in recruitment. However, the Waikato River is still recognised as being the largest source of glass eel in New Zealand.

Tuna have a complex life stage and are long-lived. Spawning occurs in oceanic waters in the South Pacific and larvae move from the oceanic spawning towards rivers which they enter as elvers. Elvers are good climbers so tuna (especially longfin tuna) can colonise small streams near the coast as well as those at high altitudes. Tuna occupy a wide range of habitats (small streams, lakes, large rivers, wetlands) and they grow and develop in freshwater habitats until they reach maturity. At this time these potential spawners migrate back downriver and out to sea. Because of their extensive migrations and long life to maturation, they are a difficult fishery to manage, notably because the relative importance and interaction between habitat, recruitment and fishing pressure have not been quantified. Furthermore, as there is no control on the life stages of tuna while at sea, the restoration of the tuna fishery has had to rely on activities that enhance the population while in freshwater.

The main pressures known to reduce the abundance of tuna are over-harvesting (commercial, recreational and cultural), habitat loss (including both riverine and lacustrine habitats), and loss of connectivity for migrations between the sea and freshwater habitats. Other pressures may arise from competition (e.g., with exotic fish species such as catfish), predation on the vulnerable juvenile stages in rivers and lakes, and marine factors influencing the survival and recruitment of elvers to river mouths. The impact of these latter factors is unknown; consequently four broad approaches to the restoration of tuna stocks contributing to the Waikato fishery are possible at present and include:

1. Restoring or creating new adult tuna habitat within the Waikato River.

2. Restoring upstream passage by overcoming barriers created by anthropogenic upstream migration barriers, notably those created by hydroelectric dams, floodgates and tidegates so as to ensure recruits can reach the available habitats.

3. Restoring migration downriver for adult spawners to maximise recruitment potential.

4. Revising tuna catch regulations to maximise the return per recruit and ensure that sufficient adults reach sexual maturity. (These regulations will need to be applied, not only within the Waikato catchment, but nationwide through catch limits, raahui (a temporary ritual prohibition) and the creation of

reserves. For shortfins there may need to be coordination of control with Australian authorities in recognition that shortfins from Australia and New Zealand may be a single species; Smith et al., 2001).

2. Goals for restoration

Potential goals for the restoration of tuna that are related to the aspirations of iwi expressed during the consultation phase (e.g., commercial fishery development, more tuna for cultural purposes, tuna as an indicator of river health) could include:

1. Development and implementation within the Waikato of a shortfin tuna (*A. australis*) and longfin tuna (*A. dieffenbachii*) management plan (including rules on harvest numbers and size) that permits the escapement to the sea of at least 40 percent[4] of the adult spawners[5] that would have existed before anthropogenic influences reduced the stock. Such a plan should also include consideration of the benefits or otherwise of harvesting glass tuna and elvers.

2. Restoration and creation of new adult tuna habitat in the Waikato River that would support a tuna stock equivalent to that currently harvested downstream of Karaapiro Dam (i.e., about 100 tonnes or 10 times the estimated traditional harvest of 10 tonnes).

3. Overcoming all barriers to the migration of elvers into significant tuna habitats within the catchment and implement land and other management practices that maximise survival of recruits.

4. Reducing the impact of migration barriers for adult spawners moving downstream, to ensure the escapement from the Waikato catchment meets the proposed management plan objective.

3. Actions

3.1 Management of the tuna fishery

To restore the tuna culture within the Waikato River a tuna management plan with clear and realistic goals needs to be implemented. The plan will need to identify funding sources and will need to be drafted in conjunction with stakeholders so their aspirations, knowledge and concerns can be captured. The plan will need to be a living document that will take account of local, regional and national interest and

[4] The 40 percent criteria is based on current European directive.
[5] The commercial peak harvest of the 1970s gives a fair indication of the stock that existed prior to over-harvesting and the collapse of Lakes Waahi, Whangapee and Waikare.

identify information gaps and means of answering these. Tuna population monitoring, surveillance and policing will need to be an integral part of the plan.

Action A: Develop and implement a tuna management plan

In conjunction with resource owners and managers, it will be essential to develop and implement a shortfin tuna and longfin tuna management plan that will aim to restore and maintain a sustainable tuna fishery in the Waikato. The Sections that follow include some of the issues and actions that could be considered in the proposed plan. (Also, refer to Appendix 7: Fisheries management, which gives the broader context for fisheries management in the Waikato River).

3.2 Restoration of habitat

If a target of an additional 100 tonnes of tuna stock is set, some 2,500 hectares of productive pond habitat[6] would need to be created/restored. Consequently, to improve the tuna population, in addition to building new ponds, restoring and/or enhancing existing lakes and streams, and continuing to stock the hydro reservoirs will be required. Above all, it is also essential that no further degradation and loss of tuna habitat occurs.

Other innovative measures that could be taken to increase tuna habitat but which are not developed in this assessment include:

1. <u>Iron sand mining near the river mouth (Glenbrook steel mill).</u> Instead of restoring the mine workings to pine forest, create ponds and wetlands (e.g., create new dune lakes). Advantages are high quality input water and lack of connectivity for pest fish. (No cost or loss of productive land would be expected.)

2. <u>Sand mining operations</u>. Promote sand mining where lakes, ponds and wetlands can be created once mining is complete. (No cost or loss of any additional productive land would be expected.)

3. <u>Open pit coal and rock mining</u>. Maximise the creation of lakes and wetland as part of mine restoration practices rather than infill pits to restore pasture. (No cost or loss of any additional productive land would be expected.)

4. <u>Underground coal mining</u>. Allow land subsidence for underground mines to create and/or restore wetlands, ponds and lakes. Compensation by the mining industry would be required.

[6] Assumes a productive habitat can produce on average 40 kilograms per hectare per year; see Chisnall and Martin (2002) for raw figure.

Action B: Restore lowland stream habitat below the Karaapiro Dam

The Waikato catchment has an estimated 3,460 kilometres of drains and managed waterways, the largest of any district/regional council in New Zealand (Beentjes et al., 2005). According to Hicks et al., (2004) fish biomass in productive lowland stream habitat ranges between 81 and 90 grams per square metre with tuna making 96–99 percent of the biomass. Assuming an average drain width of one metre, each 10 kilometres of stream (equivalent to one hectare of waterway) could potentially support at least 800 kilograms of tuna.

There are various methods that could potentially be employed to improve stream tuna habitat:

1. Increase the sinuosity and habitat diversity of lowland stream and farm drain.
2. Improve water quality by reducing nutrient inputs (as long as this does not significantly reduce aquatic productivity). Tuna are relatively tolerant of poor water quality but some of their main prey species are not.
3. Plant the northern banks of exposed streams running through farmland with trees and shrub cover to reduce macrophytic and emergent plant growth within the channels. (This would also reduce the need for drain clearing and would thus prevent the loss of tuna through this process – see Beentjes et al., 2005.)
4. In tidal reaches, restore some natural water level fluctuation (and hence flushing) to improve water quality upstream of floodgates.
5. Encourage the retention of woody debris in stream channels. Note however that this may increase the risk of flooding in some situations.
6. Ensure upstream and downstream passage within drains and waterways that are fitted with pumping stations.

Of these potential methods for improving and increasing stream habitat for tuna, control of emergent and aquatic vegetation in small streams choked with vegetation is considered to be the most viable because this problem has been observed to affect long reaches of lowland stream habitat and it depends on low-cost viable technologies. Based on existing GIS (geographical information system) data there are about 6,400 kilometres of riverine habitat within the Waikato River basin below Karaapiro Dam with a slope equal to or less than three percent (i.e., habitat that could be considered ideal for shortfins). Much of this habitat on dairy farms is expected to eventually be electric fenced to exclude livestock as part of the Dairying and Clean Stream Accord. However, only 38 percent of pastoral stream bank was fenced in 2007 in the Waipa River and Waikato River below Karaapiro Dam, and small streams and drains had the least proportion fenced (Storey, 2010). As this accord focuses on larger streams (‘wider than a stride’) many small streams suitable for tuna may not be fenced and planted. Enhancing this habitat would require planting along northern banks with tall trees and shrubs.

When considering stream restoration as a means of enhancing the tuna fishery it is important to note that Rowe et al., (1999) found that there were more than ten times as many shortfin tuna in pasture compared with forested streams and that their biomass was 30 times greater in pasture. They also found that there was little difference in longfin tuna density between pasture and forested streams, but that longfin biomass was four times greater in pasture streams. Similarly, Hicks et al., (2004) reported that pasture streams were more productive shortfin tuna habitats than forested ones. Consequently, partial riparian shade to stabilise banks and provide cover, without causing marked reduction in instream primary production, is required.

Action C: Enhance the population in the hydro reservoirs and tributaries

Action C1

Currently the most significant upstream migration barriers for elvers in the Waikato catchments are the hydro and water supply dams. Based on existing GIS records there are about 16,700 kilometres of waterways between the river mouth and Huka Falls with about 6,700 kilometres upstream of Karaapiro Dam. As tuna previously had relatively free access up to Arapuni Dam it is estimated that providing reliable recruitment upstream of Arapuni (as currently occurs through elver trap and transfer operations) would potentially allow the full colonisation of 5,400 kilometres of 'additional' riverine habitat. It is not known how accessible these upstream habitats are, or how many tuna they could support, but stocking tuna upstream of Arapuni may add some 30 percent 'additional' riverine habitat for tuna to exploit. On this basis it is recommended that the present catch and transfer of elvers from Karaapiro Dam to upstream habitats be continued. This, in effect, creates new tuna habitat above Arapuni that compensates for some of the lost habitat in the Waikato below this dam. It also helps to compensate for the reduction in the commercial tuna fishery below Karaapiro.

Action C2

At present around two million elvers reach Karaapiro Dam and are transferred to the reservoirs upstream. However, based on existing records, only about two percent of elvers transferred are eventually harvested. The reasons for this low 'return' are not known but are expected to be related to their small size and could include slow growth, high predation (e.g., by trout and shags), mortality related to handling stress, inability to find juvenile rearing habitats and natural losses as elvers continue to migrate to the next dam. Determining the cause of the losses needs to be investigated. Monitoring of the population is also essential to ensure optimum stocking rate and maximum gain.

Actions C3 and C4

These losses are thought to be related to a high post-stocking mortality of elvers and this may be reduced if the stocked tuna are larger. Therefore, there may be an advantage in on-growing elvers to a larger size in intensive culture farms, or in farm ponds so long as predators, including large tuna, are excluded. This would be a simple and cheap option. To assess the effectiveness of such measures up to 40 percent of the elvers reaching Karaapiro each year (i.e., 800,000 elvers) could be used in an initial trial without compromising existing seeding operations. If the bottleneck for tuna production in the hydro reservoirs is indeed a high mortality before the elvers reach 20 grams, and that mortality thereafter is minimal, then it may be possible to increase the current harvest by at least 10 fold by on-growing the harvested elvers before release. Even if such an operation does not fully produce the expected gains, creating on-growing facilities should increase the output from the fishery.

Action D: Create ponds

Small ponds typically contain about four times the biomass of tuna than large water bodies[7]. To create small ponds, marginal low-lying pasture and gullies could be excavated and/or dammed, allowed to fill with water and converted to tuna habitat.

Action D1

Stock watering dams are productive tuna habitats and are relatively easy to construct with modern machinery. It is anticipated that these dams, or series of dams, would each provide about 2,000 square metres of open productive tuna habitat. Construction of some 1,000 such ponds would add 200 hectares of productive tuna habitat. However, many of these dams may need to be stocked with elvers, especially those constructed off-line and away from a stream channel. The main issue with this approach is that such waters generally occur on private land and public or river iwi access to the tuna stock created cannot be guaranteed or controlled. Where access is not available there is still value in creating ponds as they would effectively provide reserves for spawners. One potential danger with this option would be losses of tuna caused by poor water quality, cyanobacterial blooms and avian predators.

Action D2

There are currently plans to restore five to six hectares of tuna habitat by creating pond and wetlands on the left bank of the Waikato River at Huntly. This proposal could serve as a model for the contemplated restoration of some 500 hectares of low-lying marginal land in the lower Waikato River.

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[7] Chisnall and Martin (2002) estimated the population of tuna in small ponds (e.g., less than 2,000 square metres) at 40 kilograms per hectare while the estimate for large lakes like Waihora (Ellesmere) is around nine kilograms per hectare.

Action E: Move stop banks to create larger flood plains

Tuna make extensive use of land invertebrates during floods (Chisnall, 1987) and this periodic supply of terrestrial food source may provide a significant boost to growth and production. If so, the creation of stop banks and flood control measures has reduced such habitat and there may be potential benefits in increasing flood plain size by moving stop banks, floodgates and pumping stations further back from the water channels. The objective of this action would be to increase the flood-created feeding areas for tuna (i.e., restore flood plains) along the banks of the river in order to increase the growth of tuna. Removal or replacement of these structures would have significant ramifications and costs and therefore needs to be well justified. At present, the benefit of flood-plain feeding to tuna has not been quantified and research (e.g., comparison of isotopic carbon ratios in muscle tissue) would be required to determine the proportion of biomass originating from terrestrial (flood plains) as against aquatic (riverine) sources.

Action F: Partial restoration of shallow lakes for tuna habitat

Shallow lakes are major and productive habitats for tuna (McDowall, 1990) and the riverine lakes in the Waikato are no exception. Lake Waikare was initially a very productive tuna fishery with 85 tonnes reported caught from the lake in 1980 (Todd, 1981). According to New Zealand Eel, a major tuna processor in the Waikato region, it is now a relatively poor fishery (Phillip Walters, pers. comm.). The exact causes for the collapse are not known but are likely to include overfishing, lack of access for elvers[8], the lowering of the lake as part of the creation of the existing flood protection scheme, drainage of the surrounding wetland, decreased water level fluctuation, a decline in water quality (affecting food resources) and increased competition for food from pest fish species (e.g., brown bullhead catfish, koi carp, rudd). Tuna have also declined in Lakes Whangapee and Waahi for much the same reasons. There has therefore been a large loss of lacustrine habitat for tuna in the Waikato.

Comprehensive restoration of Lake Waikare (and/or the other lakes) would be challenging, because they are key parts of the Waikato Flood Protection scheme. Provision of greater flushing flows from the Waikato River via the Te Onetea Stream may improve Lake Waikare but would require additional piping under State Highway 1, widening of the access stream channel, and installation of additional water control gates (flow can reverse to the Waikato during periods of low river level). Other measures that could be taken to restore the tuna fishery in these lakes include the formation of wave barriers that would reduce the effect of wave action on sediment re-suspension and would double as additional littoral habitat. These wave barriers

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[8] Fish passage restored in 2003 by installing a fish pass adjacent to the control gate at the outlet of the lake.

could be created by inserting rows of groynes (e.g., maanuka fences) and creating islands and causeways by the importation of rock and dredging of lake sediment. As none of these partial mitigation measures are proven, they are not considered further in the present assessment but clearly require further investigation (see also Appendix 12: Shallow lakes).

If the shallow lakes in the Lower Waikato can be restored with macrophytes re-established and pest fish eradicated or controlled then a large amount of tuna habitat would potentially be restored. One of the major issues with this scenario is how to prevent recolonisation by pest fish notably during floods when river water backflows up the outlets and enters the lakes. For lakes such as Waahi which are now protected by stop banks and floodgates one could conceive a raised weir or bund with a pumping station which isolates the lake from the river at all but extreme flows. Such structures would, however, not only deny pest fish access back upstream but also pose recruitment problems for indigenous fish species. At present, a ramp fish pass could be readily designed to allow elvers, climbing galaxiids and piiharau (lamprey) to enter the lake yet exclude pest fish. However, research is required to develop and prove a design that could provide access for species such as iinanga (whitebait), smelt, and mullet but not pest fish. In the absence of this, it is only possible to restore the lakes for tuna and this assumes that removal of pest fish is possible and warranted.

3.3 Improved upstream passage and survival of juvenile tuna

To restore the tuna population in the streams and tributaries of the Waikato River below the Karaapiro Dam, all anthropogenic instream barriers could be retrofitted or managed so as to maximise the upstream passage of elvers and minimise losses from fish and bird predation at the barriers. The only exception to this would be in catchments where providing passage for tuna would have a significant and demonstrable adverse affect on the existing biota (e.g., impacts on threatened galaxiid populations in the Mangatangi and Mangatawhiri reservoirs).

Apart from dams, anthropogenic barriers to elver migration are created primarily by pump stations and perched culverts. Pump stations occur mostly in the lower catchment and have the greatest impact where there is no direct hydrological connection between the upstream habitat and the river downstream (i.e., recruitment is severely impeded). The number of pump stations that fit this category is unknown.

There are also a large number of farm-track culverts that are barriers to fish at all flows and these could prevent tuna from colonising upstream habitat. The location of these is unknown (only a very small fraction of all culverts have been surveyed to date).

Action G: Remove restrictions on elver passage created by culverts

Jones (2008) estimated that, of the estimated 3.6 culverts per 100 hectares in the Waikato Region, 36 percent or 1.3 out of 100 hectares were a barrier to all fish at all flows (i.e., to tuna as well as other species). As the catchment area for the lower Waikato River below Karaapiro (excluding the major lakes) is approximately 6,500 square kilometres, approximately 8,500 culverts could be limiting elver recruitment upstream. Some of these culverts will be more serious barriers than others because they restrict habitat to a greater length of stream and/or are impassable at all flows. At present, the potential impact of individual barriers on elver recruitment is unknown and site-specific surveys would be required to locate and distinguish high from low priority barriers and to estimate the length of habitat presently not colonised by tuna. This action links with a similar one for banded kookopu (addressed in Appendix 6: Whitebait) but is more extensive as tuna have a greater inland penetration. If all the farm-track culverts restricting banded kookopu are assumed to be replaced under that action, then the 4,250 culverts that need to be retrofitted for tuna can be reduced by 1,450 giving a total of about 2,800.

The restriction for elver passage posed by perched culverts can be readily fixed through the retrofitting of a rope-based material to the downstream lip of the culvert. This technology is already in use in Europe notably in Ireland and has recently been tested on banded kookopu migrants (David et al., 2009). However it is only suitable for small juvenile tuna less than 120 millimetres in length (i.e., glass tuna and elvers).

3.4 Provide passage downstream for spawning tuna

In habitats with no safe downstream passage (e.g., reservoirs and catchments protected by pump stations) it is recommended that the harvest of tuna is maximised to reduce the number of adults reaching sexual maturity[9]. This means that the proportion of tuna remaining and reaching sexual maturity would be minimised in order to reduce the unavoidable loss of tuna during migration downriver. However, as some habitat will remain unfishable and some adults will invariably escape capture, some spawners will attempt to pass through intakes. Capturing these tuna before they reach the intake is theoretically possible (see harvest Section below) but so far has proved relatively ineffective in other catchments (Boubée et al., 2008). Consequently, the following actions could be considered:

[9] Up to eight percent of the stock are potential spawners in un-fished population versus only 0.04 percent in fished populations (Beentjes et al., 2005).

Action H: Install downstream passage for adult tuna at pump stations

Apart from a few Archimedes[10] screw pumps, most of the 65 flood pump stations installed in the Waikato do not allow the safe downstream passage of adult tuna. To remedy the situation it will be necessary to install fine screens to prevent the tuna from entering the pumps (20 millimetre spacing or less). The screens need to be large enough so the through-screen water velocities remain below half a metre per second and do not cause the tuna to impinge on the screens. These screens will require automated screen cleaners to ensure their efficiency. Downstream passage may then need to be provided by installing at least one additional tuna-friendly pump such as a Ventura pump or an Archimedes screw pump at each station. Provision of such fish-friendly flood pumps would allow the safe escape of adult spawners from an estimated 600 kilometres of waterways (i.e., six percent of the total length of waterways downstream of Karaapiro Dam).

Action I: Screen hydro and water supply dams

There is currently no safe downstream passage available for adult tuna spawners from the majority of the Waikato catchment reservoirs (hydro or water supply). Placement of fine screens (20 millimetre spacing or less) with a low through-screen velocity (half a metre per second or less) in the form of a fish training wall could be used to shepherd migrant tuna into bypasses and/or onto holding. From there, the migrants could be passed safely below the last barrier or trucked and released there.

3.5 Harvest controls to increase the number of adult migrants going to sea

Although largely unquantified, there is little doubt that tuna recruitment has declined over the last five decades (Cairns, 1941; Jellyman et al., 2009). To increase recruitment, more fish need to reach sexual maturity and out-migrate to spawning grounds at sea. This is a national (international in case of shortfins) issue but as the Waikato has the largest tuna fishery within New Zealand, it has a major part to play in the restoration.

With the lower recruitment it is essential that survival of each recruit is maximised and that maximum production is obtained from each recruit (i.e., increase the permitted minimum harvest size[11]). In addition, large tuna notably longfins, are known to become piscivorous once they reach 400–500 millimetres in size. Retaining large tuna in the system, particularly the lakes, could exert some pressure on juvenile pest fish such as koi carp and rudd.

[10] These pumps are commonly used in the Netherlands to provide downstream passage for tuna.
[11] Under the current minimum harvest size limit it takes four to five tuna to produce one kilogram of tuna but this number would be smaller if the minimum size was increased.

Two other approaches to control harvest are possible. The creation of reserves free of any harvest is one and the implementation of a more restrictive maximum size limit is the other.

Action J: Creation of reserves

If Lake Whangapee is restored, the entire Lake Whangapee catchment could be made into a reserve free of any traditional, recreational or commercial tuna harvest. This lake was reported to have produced 60 tonnes of tuna in 1980 (McLea, 1986). This is about 15 percent of the total catch for the region at the time so would, if protected and enhanced, provide much of the proposed goal of providing for the escapement of 40 percent of adult spawners that would have existed with no anthropogenic influences. The remaining spawner escapement could be provided by banning harvest (commercial, recreational or traditional) in most if not all of the first and second order streams within the catchment. Imposing more stringent maximum size harvest limit could also be used to reach the escapement goal (see Section below) and would need to be carefully considered when the catchment's tuna management plan is drafted.

The loss of potential harvest resulting from these measures would be compensated by improving the fishery in the rest of the Waikato catchment.

The creation of a tuna fishery reserve in the Lake Whangapee catchment would in all likelihood require the creation of regulations under the Fisheries Act and possibly a change in legislation to prohibit commercial and recreational fishing. Adequate policing of such regulations would be required and under the current Fisheries Act such action is the responsibility of the Ministry of Fisheries. However, customary takes would also need to be considered and can potentially be controlled by a raahui. These issues and requirements would need to be addressed through the development and implementation of a tuna management plan (see Action A).

Action K: Change in the minimum and maximum allowable harvest sizes

There is much uncertainty in setting harvest size limits to achieve restoration goals and research is required, but as an interim measure and until robust supporting information becomes available the following harvest rules could be considered when the proposed tuna management plan is drafted:

1. Except for the purpose of restocking, no tuna smaller than 450 grams to be harvested from the catchment[12].

2. Except for the purpose of translocation downstream of migration barriers, no tuna larger than two kilograms (i.e., close to the maximum size for shortfin female spawners) is to be harvested from the catchment [13].

3. Except at sites specifically excluded in the proposed tuna management plans, all spawners (downstream migrant tuna) captured within the catchment are to be released to ensure their survival and where necessary (i.e., in reservoirs with no safe downstream passage, upstream of flood pumps, and in landlocked lakes/ponds) transported downstream of migration barriers.

It is recognised that such suggestions would have significant and immediate implications for the traditional and commercial harvest of tuna and there would be a substantial reduction in harvest for several years until tuna achieved the larger average size. Development and implementation of such proposed changes would be the responsibility of the Ministry of Fisheries and may need to be staged over several years to allow the fishery to adjust.

4. Benefits

Some of the potential actions considered above are not feasible at present because their success is dependant on research to prove the concept, or there are issues over governance and access to the fishery that limit harvest. For example, an increase in the number of farm ponds would result in more tuna habitat in the Waikato River but unless accessible by fishers, would be of no immediate benefit in terms of harvest. These non-harvested ponds would nevertheless provide a significant source of spawners and so would have long-term benefits to the fishery. Similarly, the value of flood plains as a key feeding habitat for tuna requires confirmation before plans to reposition or remove flood banks can be considered. If these actions are excluded, then execution of the feasible ones would result in three major outcomes. These would be (1) the creation of new or better tuna fisheries in the lakes and streams above the hydro dams; (2) an increase in lowland stream habitat capable of supporting tuna and accessible to them; and (3) an increase in the escapement of spawning tuna to sea to help increase recruitment nationally.

[12] A vent size in fyke nets of 31 millimetres (currently 25 millimetres) would allow this target to be met. Such a simple change has the potential to increase harvest weight for the same number of tuna captured by 25–30 percent.

[13] The current limit is four kilograms but very few tuna larger than two kilograms are caught at present so the impact on commercial fishers of not harvesting the largest and most fecund female tuna would not be substantial.

5. Risks and probability of success

5.1 Implement a tuna management plan and establish reserves (Actions A, J and K)

Harvest limits as well as the creation of reserves will require changes to the present fishery legislation and may require quota compensation/adjustment. Above all, such measures will require control and enforcement. The major risk with this approach is associated with the need for legislative change that may have ramifications for other regions of New Zealand and attract opposition from tuna stakeholders outside the Waikato.

5.2 Restoration of tuna habitat in streams (Action B)

The major risk associated with this action is that the increase in tuna habitat arising from it is unknown. The total kilometres of stream that are currently uninhabitable for tuna because of prolific vegetation growth and/or poor water quality associated with this, are substantial but have not been measured. Furthermore, many of the weed problems in such streams may not be resolved by riparian planting on the northern side alone. It is therefore not possible at this time to quantify the increase in stream habitat that will result from riparian tree planting. Furthermore, the long-term retention of a riparian margin tall enough and dense enough to shade the stream cannot be guaranteed. However, it is known that small, open streams can provide good habitat for large numbers of tuna and that better management of the instream vegetation will provide good tuna habitat. Such management will produce a clear benefit to tuna, but because tuna are slow growing and long-lived it will take a decade or more before measurable effects are seen.

5.3 Enhance the population in the reservoirs and tributaries (Action C)

The trap and transfer operation at the Karaapiro Dam has allowed elvers to be captured and stocked into the hydro reservoirs. This has resulted in the development of fisheries in the reservoirs and possibly in the tributary streams. At present catch rates are relatively low and the reasons for this need to be determined. It may be that stocking practices need improvement or that the tuna are too small and need to be on-grown to increase survival when stocked. Research is therefore required to identify how to enhance the stocking. If mortality soon after stocking is the main limitation, then the culture method may improve survival. The method is however untested in New Zealand and lack of seed stock and the high cost have failed to produce the desired results in Europe (and has been virtually abandoned in Australia).

Another major risk with this approach is the uncertainty about continued supply of elvers at the base of the Karaapiro Dam. Although the number of elvers translocated has been relatively stable in the last 10 years, it is not known if present catches will be sustained in the foreseeable future.

Another risk is that there will be additional adult spawners entering the turbines and killed. There will inevitably be a public reaction against such losses so management of the fisheries in these reservoirs needs to ensure a high harvest rate.

The issue of glass tuna harvest and establishment of a tuna aquaculture industry should also be considered. Currently it is not possible to artificially produce seed stock and establishment of a tuna farming venture in New Zealand (or with partners overseas) would invariably require access to Waikato River glass tuna.

5.4 Creation of tuna ponds (Action D)

The construction of ponds is relatively straightforward from an engineering point of view, especially where these ponds are off-line (i.e., not across a stream channel) or on ephemeral streams. The Waikato Regional Plan has a permitted activity rule allowing (with conditions) creation of farm dams in the bed of ephemeral rivers or streams, where the catchment area is less than one square kilometre (100 hectares), and the maximum water depth of the pond is less than three metres, and/or the dam retains not more than 20,000 cubic metres of water. Larger dams require resource consents.

There is a risk in that the supply of elvers for such ponds may be limited. At present, the elvers that accumulate at the base of the Karaapiro Dam would provide the main source, but the bulk of these may be required for stocking the hydro reservoirs, leaving few for stocking ponds.

For ponds built within stream channels, recruitment of elvers would not be a limitation provided an elver ramp is constructed to allow them to climb the weir. However, such in-line dams and ponds can impact on the upstream passage of other fish (e.g., iinanga) and consents for such dams may be harder to obtain than for off-line dams.

This aside, there are some large expanses of marginal, lowland pasture close to the banks of the Waikato where excavation could be used to create suitable pond habitat for tuna. This assumes that the land is either already in public ownership or can be purchased. The success of this action is therefore dependant on successful consultation with landowners to enter into perpetual access agreements or to agree to the sale of land so that an access can be provided.

The site-specific issues affecting pond creation mean that potential locations for tuna ponds in the Waikato River catchment cannot be determined at present. Hence the total area of pond habitat that can be created cannot be calculated.

5.5 Elver recruitment past culverts (Action G)

The location of culverts posing barriers to elver upstream migration needs to be determined before culverts to be replaced or retrofitted can be identified. Most of the culverts affecting elver passage upstream will be associated with farm tracks and therefore occur on private property. Access to these sites may therefore be a limitation. Regular maintenance of simple retrofits, notably of the rope ladders, will be required and this may constrain the long-term use of such technology. A permanent fix would require replacement of perched culverts with larger ones but this would not be economically justifiable except where a culvert blocks access to a large amount of tuna habitat.

5.6 Creating downstream passage for tuna (Action H and I)

The screening of water intakes at hydropower stations is technically feasible (although extremely expensive), but the shepherding of tuna into holding pens or bypasses is more problematic and dependent on specific characteristics of the dam. Although such technologies have been specifically designed for and worked for some fish overseas (notably salmonids), success cannot be guaranteed at all sites.

The creation of passage for downstream migrants over weirs at pump stations through the use of Archimedes screw pumps or Ventura pumps is more feasible and these are already in place in Europe. The major risk with this approach involves blockage of the inlets with debris, which can be overcome through careful monitoring, maintenance and coarse screening.

6. Costs

6.1 Management plan (Action A)

Developing and implementing a robust tuna management plan that takes account of the aspirations of stakeholders and robust science (traditional and modern) will most likely take five years. Resource requirements to develop a proposed plan are anticipated to be 0.5 of an FTE (full-time equivalent) per year at an estimated annual operational cost of $125,000. Implementation of the plan thereafter is expected to also take 0.5 of an FTE but will be dependent on legislative implications. It will not be possible to determine the cost of policing and monitoring until the draft plan is complete.

6.2 Restoration of stream habitat (Action B)

It is apparent that many lowland streams contain reaches where the habitat for tuna has been lost because of heavy emergent and submerged weed growth. Shading from trees and tall shrubs (planted on the northern side) can help reduce this, but channel excavation, mechanical harvesting and herbicide spraying will continue to be necessary in some reaches, even though this may impact on water quality. This is because weed control is an integral part of maintaining the flow of water in lowland streams during flood events.

Assuming a two metre wide riparian strip (required for shade trees only on one side), the cost of planting is estimated at about $2,000 per kilometre. Fencing is in theory already in place on Fonterra-supplier dairy farms under the Dairying and Clean Stream Accord. However most of this is single hot wire and would not provide permanent protection. Cost of re-fencing is estimated at $18,000 per kilometre for a post-and-batten fence and $5,000 per kilometre for multi-wire electric fencing. The loss of farmland (assuming a fence is already present one metre away from the stream bank) is estimated to be $1,000 per kilometre. The minimum total capital (including loss of pasture land) is therefore over $8,000per kilometre of stream. There will also need to be an annual maintenance cost of $4,000 per kilometre per annum for four years to allow the planting to fully develop.

The length of stream to which this cost would apply is not known at present and would require site surveys to determine. However, the total length of stream habitat for shortfin tuna below Karaapiro is estimated at 6,400 kilometres, of which 25 percent (1,600 kilometres) may be suitable for riparian planting to provide shade and reduce vegetation in the stream channel. On this assumption the minimum capital cost would be $12.8 million, with an annual maintenance cost of $6.4 million over 10 years. Total cost over a 30 year period is estimated at $76.8 million.

6.3 Elver trap and transfer programme at Karaapiro (Action C)

<u>Actions C1 and C2</u>

The annual cost of the trap and transfer programme at Karaapiro is currently in the order of $20,000 per year. This is currently being met by the Eel Enhancement Company but Mighty River Power also maintains the trapping facility. Monitoring is done by Ministry of Fisheries as part of their population monitoring and reporting commitments. There is no requirement (e.g., through resource consents) for long-term maintenance operation or monitoring of the current facilities and programme (estimated at $60,000 to $80,000 per year for both stocking and monitoring). Similarly there is no provision in place for new work to improve the stocking regimes so that the developing fishery is fully extended. This will be a key step in maintaining and preferably enhancing the tuna fishery above the hydro dams to compensate for losses downstream. The total cost of Actions C1 and C2 over a 30 year period is estimated at $6.9 million.

Actions C3 and C4

If research were to establish that the on-growing of tuna before stocking into the reservoirs significantly improves survivorship and hence catch rates, culture of elvers would be required. The set-up costs for this are estimated to be $1.3 million with ongoing maintenance costs of $0.55 million per year. Total cost over a 30 year period is estimated at $17.8 million.

6.4 Creation of more pond habitat for tuna (Action D)

Action D1

The creation of 200 hectares of pond habitat for tuna would require the construction of 1,000 ponds with a mean surface area of 0.2 hectares. A riparian buffer will be required around each pond so each pond will require 0.6 hectares of land to be retired. The estimated cost of building these farm ponds is estimated at $28.3 million (includes three years of maintenance after construction but not land or loss of production costs).

Action D2

The excavation of 100 five to six hectare low-lying wetland to create ponds is estimated at $72.5 million. This cost includes an initial 10 years of maintenance but assumes that the area to be restored is either non-productive or already in public ownership.

6.5 Move stop banks (Action E)

It is not possible to cost this action until a full assessment and research is complete.

6.6 Partial restoration of shallow lakes (Action F)

Lake restoration is addressed in Appendix 12: Shallow lakes but it is also noted that for Lake Waikare, the estimated cost of widening the Te Onetea Stream (including installation of new a floodgate and culvert under State Highway 1) is estimated at $0.7 million. The cost of installing wave barriers in the lakes is estimated at $1.7 million per kilometre.

6.7 Upstream passage at culverts (Action G)

For the purposes of costing this action, it is assumed that 50 percent (i.e., 4,250) of the culverts expected to pose some barrier to tuna could be a high priority. It is estimated that 4,250 culverts under farm tracks could provide a barrier to elver upstream migration. Some 1,450 of these would need retrofitting to enhance banded kookopu (whitebait species) and once modified for these would also allow free passage for elvers. The benefits of such actions is unknown as the quantity and quality of the habitat is unknown.

Retrofitting overhanging culverts to allow elver passage upstream is relatively straightforward and involves attaching a length of frayed rope or similar to the lip of each culvert and allow this to hang into the pool below. Retrofitting is estimated to cost in the order of $700 per culvert giving a total cost of $1.9 million.

6.8 Increased spawner escapement (Actions H–K)

<u>Action H</u>

The addition of tuna passage to pump station weirs via Ventura pumps or Archimedes screw pumps will allow spawner tuna to surmount the weirs and migrate to sea. The cost of such devices varies depending on the size of the installation but could reach $1.5 million at the larger sites. Retrofitting all 65 pump stations could therefore reach $96.5 million. Because of the high cost it will be important to assess each site and determine the relative gain from retrofitting each station. Furthermore, in some cases safe passage may be possible with a simple and partial retrofit.

<u>Action I</u>

The screening of hydro dam intakes at eight dams to protect tuna from entering the turbines is a major expense and is estimated to cost approximately $600 million. The cost of setting up appropriate bypasses and collection facilities for tuna at each dam will be site specific but are expected to be in the order of $50 million. Cost of transporting the tuna downstream is estimated at $70,000 per year.

<u>Action K</u>

Estimating costs for increasing the escapement of tuna has not been determined as this would involve a change to the legislation by the Government. Creation of reserve areas (i.e., no fishing zones) for tuna may also require legislative change and the purchase of quota (as compensation for loss of access to part of the fishery). Neither of these actions can be readily costed at present.

7. Cost comparisons

A summary of cost for the proposed mitigation actions are shown in Table 3. The regional breakdown is provided to show the distribution of costs for the hapuu associated with each region. By far the most expensive of these is screening of the hydro intakes, which are located in the upper region of the river. The management plan would affect tuna in all regions and so the cost of this has been apportioned equally among them.

Table 3: Comparison of estimated costs for the proposed restoration actions that can be costed, and the distribution of these by region

Action	Description	Total costs including capital and operational ($millions)				
		Upper	Mid	Lower	Waipa	Total
A	Management plan	0.95	0.95	0.95	0.95	3.8
B	Restore stream habitat	0.0	8.0	50.8	8.0	76.8
C1+C2	Reservoir seeding and monitoring	6.9				6.9
C3+C4	On-growing facilities	17.8				17.8
D1	Create farm ponds	4	7	7.3	10	28.3
D2	Restore lowland ponds		10	60.0	2.5	72.5
G	Culvert		0.3	1.2	0.4	1.9
H	Flood pumps			96.5		96.5
I	Hydro screening	600				600

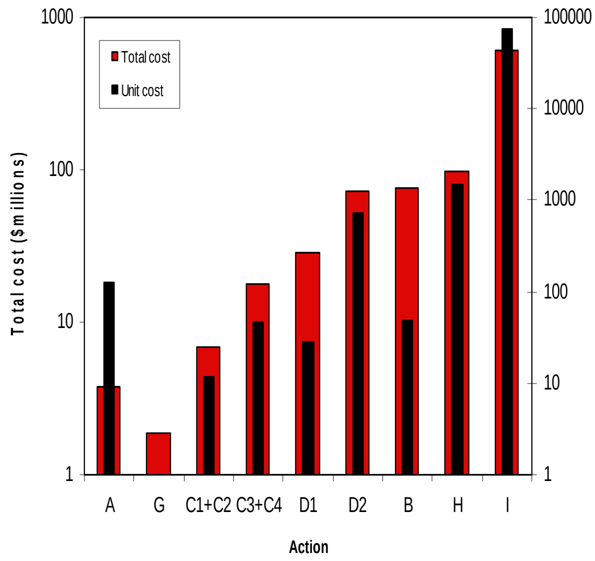
Table 4 shows the least to the most expensive action in terms of total discounted capital and operational costs for tuna restoration. Capital costs are assumed to occur in the first year (2011), whereas operational costs are occurring on an annual basis until 2040, unless specified differently. Capital and operational costs are discounted at eight percent to give the present value of costs[14]. Some costs will not change from the above as only capital costs are considered for that option and they are assumed to come in year 2011, therefore do not need to be discounted.

[14] Present value is the value on a given date of a series of future payments, discounted to reflect the time value of money and other factors such as investment risk.

Table 4: Total discounted costs of all actions.

Action label	Action	Method	Total cost discounted at 8 percent ($million)	Units
G	Retrofit culverts	Add climbing media	$1.86	2,800 culverts
C1+C2	Hydro seeding	Transfer elvers to reservoirs	$2.59	600 tonnes
A	Management	Develop plan	$3.76	30 years
C3+C4	Aquaculture	On-grow elvers for release	$7.75	384 tonnes
D1	Farm ponds	Dam gullies to create ponds	$25.97	1,000 ponds
B	Lowland stream	Plant riparian margins	$54.80	1,600 km
D2	Lowland ponds	Excavate and bund	$75.12	100 ponds
H	Pump station passage	Screen and install fish pumps	$96.53	65 pumps
I	Screen hydro intakes	Design, build, fix to intake	$600.00	8 dams

In order to provide a better overview, the total and unit costs for all actions are shown in Figure 5. Only some actions could be related consistently to an environmental outcome for each action (i.e., the dollar amount required to restore one tonne of tuna). Total tonnes of tuna restored were estimated for six actions (Table 5). Actions A and C1+C2 restore tuna at a low cost per tonne, whereas actions D1, D2 and B are more expensive (by a factor of 10) when compared to Action A (Figure 6).



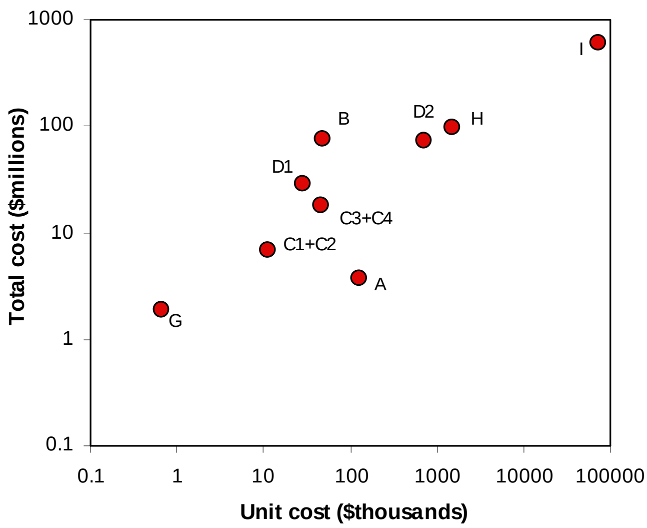


Figure 5: Comparison of total and unit costs of all actions (discounted at eight percent).

Table 5: Relative cost of actions per tonne of tuna restored

	Action	Estimate gain (tonnes)	Relative cost $/tonnes	Total cost discounted at 8 percent ($million)
A	Management plan drafting and implementation	100	$1.3	$1.9
C1+C2	Seeding of hydro reservoirs and monitoring	15	$4.3	$3.8
C3+C4	On-growing (aquaculture)	20	$20.2	$7.7
D1	Create farm ponds	12.8	$108.2	$26.0
D2	Restore low-lying ponds	8	$120.8	$54.8
B	Restore stream habitat	20	$121.8	$75.1

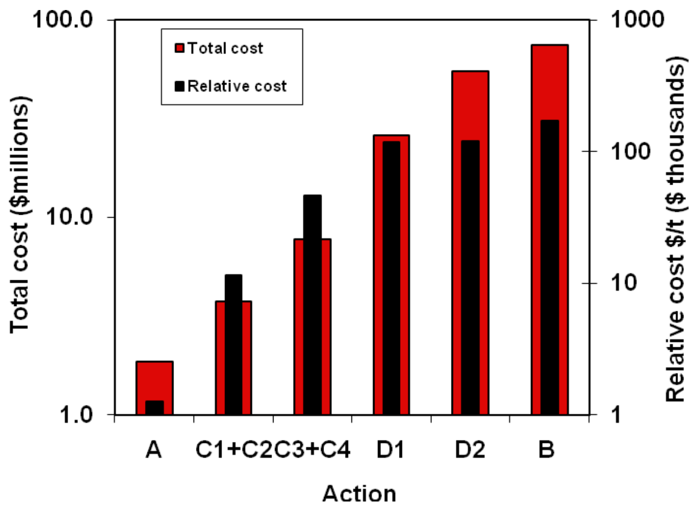


Figure 6: Total and relative cost of actions per tonne of tuna restored**.**

7.1 Summary of cost analysis

In terms of total and unit costs (without considering the environmental outcome achieved), Actions G (retrofit culverts), C1+C2 (hydro seeding and monitoring), A (management plan) and C3+C4 (aquaculture) are relatively more cost-effective than the other actions. When restoring tuna, these actions should be given priority when considering cost-efficiency.

Based on an analysis of relative gain (dollars per tonne of tuna restored for six actions), three actions clearly stand out: development of a management plan (Action A), hydro reservoir seeding (Actions C1+C2) and on-growing (C3+C4) (Table 5). There would, therefore, be most benefit in ensuring that these actions are carried out to maximum effect. The total investment required for these three actions is in the order of $13.4 million over 30 years (discounted at eight percent).

Modifying current harvest rules to maximise return per fish is another obvious means of improving returns from the fishery and this will need careful consideration when drafting the proposed tuna management plan.

All the other actions will ensure the sustainability of the fishery and could be considered as part of best practice guidelines for the catchment. Because of the very high cost and the problem of macrophyte build up involved in screening the hydro intakes, it is considered that it would be best to maximise tuna harvest in the reservoir rather than retrofit each station. Should this action be judged insufficient then installing less effective intake protection devices (e.g., electric barriers) and bypass/trap systems for spawners could be considered at key sites (i.e., possibly

Karaapiro and Arapuni (the two lowermost dams) and Ohakurii (the largest and most productive reservoir)).

8. Baseline

At present, the statistics for annual tuna harvest in the Waikato River provide the best baseline against which the success of actions to increase tuna fisheries can be judged. A sustained (for more than 15 years) increase in the present 100 tonne harvest would be the best means of determining if the enhancement measures undertaken have been successful. Harvest indicators like average size and catch-per-unit-effort would also need to be monitored (with harvest locations specified to a much finer scale than at present). It is also recommended that the number of tuna and their size distribution be measured at a number of key locations (e.g., sites where traditional harvest took place) every five years. However, these measures will be initially impacted by size restrictions on tuna catches and can be expected to result in a reduced commercial harvest of smaller tuna over the next decade. It may therefore take several decades for the effect of the actions listed above to result in a detectable increase in tuna catches. This, of course, assumes that catches are not influenced by changes in recruitment from the sea related to extraneous factors (e.g., climate variation and effects on oceanic currents and marine spawning grounds).

Measurement of tuna catches by Ministry of Fisheries currently does not encompass recreational and especially traditional takes. A baseline would need to be established if changes in the traditional take of tuna are to be measured (e.g., marae-based annual surveys). A means of measuring success would be to use traditional paa tuna methods of harvesting downstream migrating tuna (spawners) to quantify the number of out-migrants.

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Appendix 6: Whitebait

1. Introduction

The decline of whitebait fishery in the lower Waikato River was identified as a key concern for Maaori through a range of consultations with iwi (tribes) from throughout the river catchment, from the Lake Taupoo outlet down to the sea (NIWA et al., 2009). Recovery of the whitebait fishery in the lower river is required because it is an historic cultural fishery and also because the presence of large numbers of whitebait in the river is viewed as an indication of river health. Recovery of the whitebait fishery is therefore an important restoration goal for iwi in the Waikato River. However, restoration can only be achieved if the factors responsible for the decline in the fishery can be identified and reduced, and this pre-supposes that an historic decline in the fishery has occurred.

The whitebait fishery comprises two components: the juvenile fish that migrate upriver and the whitebaiters that catch them. Although a habitat-related decline in the abundance of whitebait can result in fishery decline, an increase in whitebaiters can potentially cause a decline through overfishing. The fishery may also decline because of factors not related to a change in the fish stocks. For example, river works related to flood protection may reduce the number of locations on riverbanks where whitebaiters can fish, and access to fishing locations may become restricted. Factors affecting the whitebaiters and their access to the fishery therefore need to be identified separately from those related to restoration of the river environment.

Overfishing was noted by some stakeholders as an important issue, but recent studies on the escapement of whitebait past whitebaiters' nets in the Mokau River, have indicated that escapement is high (more than 70 percent) and that overfishing of the stocks is not affecting recruitment of juveniles to adult habitats (pers. comm., Dr C. Baker, NIWA). This finding is supported by observations included in McDowall (1984) for a number of the larger, South Island west coast river fisheries. Escapement appears to be greater in large, wide rivers such as the Waikato where the whitebait can more easily evade whitebaiters' nets by swimming in midstream or in deeper waters. Overfishing is therefore not a major management issue in the Waikato, but it is apparent from Department of Conservation reports, and the media, that conflicts between whitebaiters are increasing. As the number of people fishing continues to increase, conflicts will arise because of a shortage of fishing sites along the riverbanks. This issue requires management of the whitebaiters and does not affect restoration of the fish stocks. It is therefore a governance issue requiring better education and management of whitebaiters' behaviour by the fishery managers (currently Department of Conservation). Issues relating to stand ownership, use by others and spacing are currently addressed by regulations that cover the whole of

New Zealand. However, North Island versus South Island differences are included in these and it would be possible to develop regionally specific, customised regulations for whitebait fisheries in a very large river such as the Waikato. However, this presupposes a consultative process for identifying the overarching goals for management of the Waikato whitebait fishery, and then the preparation of a review report to identify potential regulatory changes needed to meet these. This process is beyond the scope of actions designed to restore the fish stocks and river restoration and as such is not addressed further in this technical report.

In a recent review of the whitebait fishery in the lower Waikato River, Baker and James (2010) compared the annual catch of whitebait estimated from commercial buyers' records between 1930 and 1990 (Figure 1).

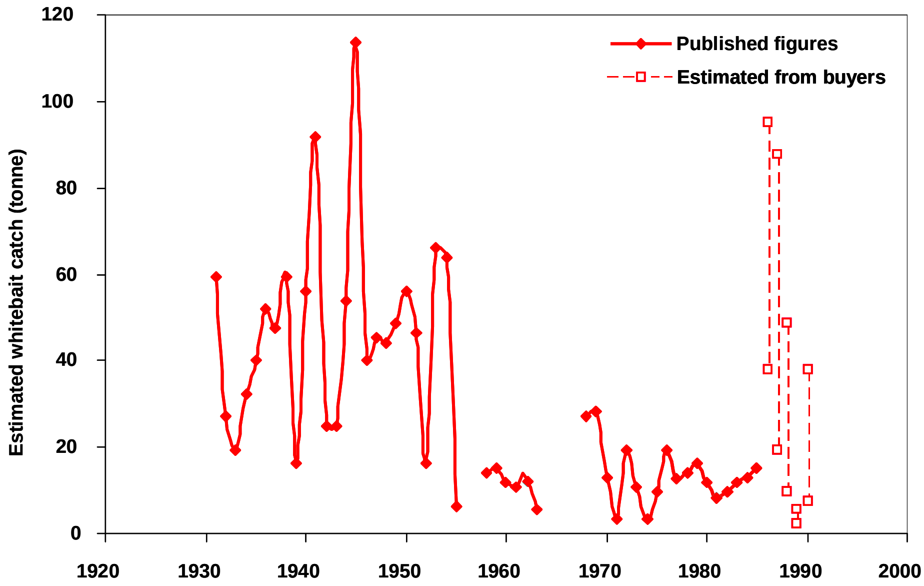

Figure 1: Estimated annual total catch of whitebait from the Waikato River (galaxiids (kookopu) plus smelt) based on catch records from Marine Department records (1931–1973), an Auckland canning factory (1958–1963) and commercial buyers' records (1975–1990). Figure from Baker and James (2010).

Although there was some evidence of a decline between 1950 and 1980, more recent data suggest that the fishery may have improved. But these figures are highly variable and are of limited value for assessing the status of the fishery. For example, the decline in commercial purchases after 1955 is likely to represent the increased use of freezers by whitebaiters to preserve and retain their surplus catch. Similarly, the increase in total catch after 1985 could well represent an increase in commercial trading caused by the increased popularity of whitebait and the high prices paid for them in the restaurant trade. Because annual purchases of whitebait reflect fluctuations in demand and supply as well as large annual variations in the catch, Baker and James (2010) concluded that the historic catch statistics are of limited use and that whereas an historic decline in the fishery has probably occurred (according to anecdotal reports), the magnitude and timing of this change is unknown.

The evidence for a decline in the whitebait fishery in the Waikato River is therefore anecdotal and based on reports of the decline of whitebait and the fisheries for these fish from other New Zealand rivers as well as in the Waikato River itself (e.g., Hayes, 1931; McDowall, 1984). The anecdotal reports clearly indicate that a decline in the number of whitebait entering rivers from the sea (and hence the river fisheries) has occurred, but there is no quantitative measure of the extent of this decline and therefore no baseline for its recovery.

A decline in the whitebait fishery can also be inferred from knowledge of the increase in threats to whitebait and from the decline of their key habitats in the Waikato River catchment. Knowledge of threats and habitat decline affecting whitebait in the Waikato River is needed to identify viable restoration goals, but this analysis needs to recognise that whitebait catches usually comprise several species of freshwater fish, each of which have differing life histories and habitats. Goals for restoration will therefore need to be specific to the different habitats and life history requirements of these species and they will vary spatially within the Waikato River catchment (i.e., the river mouth up to the Lake Taupoo outlet).

Whitebait fisheries in New Zealand rivers are based on the juvenile, upstream migrant phase of five species of galaxiid fish (McDowall, 1990). The main species is iinanga (whitebait – *Galaxias maculatus*) and its proportion in whitebaiters' catches is typically 70 to 100 percent of the total catch (McDowall and Eldon, 1980; Rowe et al., 1992). All other species combined contribute least in rivers where the catchment is dominated by pasture and most in the rivers where conversion of forest to pasture has been minimal (Rowe et al., 1992). Loss of forest cover (and replacement by pasture) has therefore been a major factor responsible for the decline of whitebait species other than iinanga. In the Waikato River catchment, where lowland forest has been largely replaced with pasture, iinanga comprised more than 85 percent of the galaxiids between 1984 and 1985. Banded kookopu (*Galaxias fasciatus*) contributed only 7.2–14.6 percent of the catch, whereas the next most common species (kooaro or *Galaxias brevipinnis*) accounted for only 0.1–0.2 percent of the catch (Stancliff et al., 1988). Historically, the proportions of banded kookopu and kooaro will have been much higher in the Waikato River fishery than today because they are all vulnerable to loss of forest cover, which has been extensive in the Waikato River catchment[1].

Juvenile banded kookopu (along with kooaro) are able to climb the near vertical rock faces of falls so long as a film of water wets the rock surface (McDowall, 1990). Unlike

[1] Giant kookopu (*Galaxias argenteus*) and shortjaw kookopu (*Galaxias postvectis*) are also minor (less than two percent) components of the catch and like kooaro and banded kookopu are dependent on forest cover.

iinanga, which has no climbing ability, banded kookopu can penetrate well inland to small first order streams, some of which may be above falls as high as 20 metres. However, the climbing whitebait species cannot climb the dry walls of dams and so have been adversely affected by dams at Karaapiro, Mangatangi and Mangatawhiri, which now prevent migrations to and from the sea. Although removal of these dams and re-afforestation of all hill-country catchments above them would increase the abundance of these climbing species in the Waikato, their contribution to the whitebait fishery would still be lower than that of iinanga and likely to be in the order of 20–30 percent. Nevertheless, the current proportion of banded kookopu in the catch (i.e., seven to 15 percent) is not negligible if it can be increased in the river catchment below Karaapiro.

The role of poorohe (adult whitebait) or smelt (*Retropinna retropinna*) in the whitebait fishery of the Waikato River is somewhat unique. Historically the catch has included large quantities of smelt which are not regarded as whitebait in other rivers. These fish were sold as No 2 rather than No 1 whitebait in the Waikato because they have a strong 'cucumber-like' smell and flavour that overwhelms the subtle taste of galaxiid whitebait. Consequently, most fishers exclude smelt from their catches. Although commercial buyers of whitebait in the Waikato River purchased one to two tonnes of smelt per annum between 1974 and 1985, when galaxiid-based whitebait was relatively scarce (Stancliff et al., 1988), catches of smelt have declined in recent times. Between 1990 and 2005, annual purchases of smelt were less than 0.25 tonnes per annum (Baker and James, 2010) and as this decline was not due to a drop in smelt abundance in the river, it reflects the decreased importance of smelt in whitebait catches. Smelt is therefore not a target species for restoration although it should be noted that there has been a decline in lacustrine (landlocked) smelt in the lowland lakes (Ward et al., 2005). Restoration of the water quality in these lakes will help restore these landlocked populations (i.e., the return of lake-dwelling versus sea-going stocks of smelt would be a co-benefit of lake restoration). Iinanga and banded kookopu are therefore the two main target species for restoration of the whitebait stocks in the Waikato River. The main factors influencing the whitebait fishery in the Waikato River are illustrated conceptually below in Figure 2.

A number of factors have combined to reduce the abundance of adult iinanga in the Waikato River stream network. These include wetland drainage, a decline in lake habitat, trout predation, pest fish increase, flood protection works and migration barriers such as weirs and culverts (McDowall, 1984; Stancliff et al., 1988; Baker and James, 2010). However, the main factor is thought to be habitat loss. In particular, a large proportion of the habitat for iinanga has been lost through wetland drainage in the Waikato River (Table 1). McDowall (1984; 1990) described this loss of iinanga habitat at a national scale and as the Waikato River once contained extensive areas of wetland, it will have been a significant factor affecting the overall abundance of adult iinanga in this river.

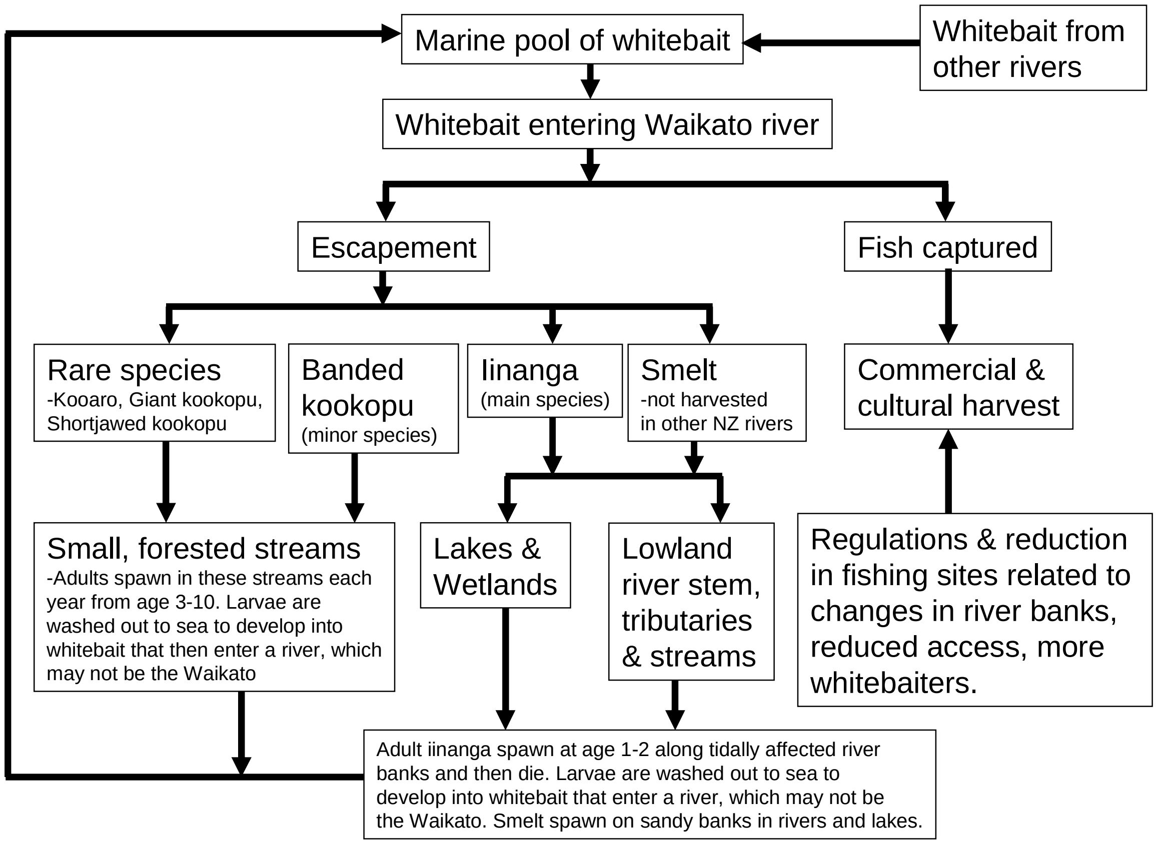

Figure 2: Conceptual model for the origin and supply of fish species sustaining the whitebait fishery in the Waikato River and the main controls/limits on whitebait fishing.

Table 1: Extent of wetland loss in the Waikato River catchment (after Cheyne, 1981).

	Area of wetland present (km^2)		% reduction
	c. 1840	1976	
Waikato	64.8	10.9	83.1
Waipa	37.6	0.1	99.6
Total	102.4	11.0	89.0

Iinanga have also declined in the riverine lakes. There is no historic data on iinanga abundance in the Waikato lakes, so any comparison of abundance must rely on comparative data. For example, iinanga abundance in Lake Waahi today is only two percent of that in Te Waihora (Lake Ellesmere) (Rowe and Kelly, 2009). Although these lakes differ in many respects, such a large difference in iinanga abundance could not be reasonably explained by such a difference in abundance. As the lakes in the lower Waikato River contain a large amount of potential iinanga habitat (Waikare, Whangapee, Waahi and Rotongaro have a combined area of 54 km^2), loss of high quality, lacustrine habitat for iinanga in the Waikato River catchment has also been substantial. The precise causes of this reduction (e.g., loss of macrophyte cover, competition for food with exotic fish species, impacts from aggressive exotic fish such as gambusia, a reduction in suitable prey species for iinanga in these lakes, impeded access in some lakes and increased predation by natural predators) are unknown. In the absence of such data, full restoration of the lakes would be required to increase iinanga abundance in these environments (see Appendix 12: Shallow lakes).

In addition, still and slow-flowing habitat for iinanga in the streams has been degraded as a consequence of the conversion of forested catchments to pasture and the removal of riparian trees and other lower-growing vegetation (apart from grasses) from the streambanks. Richardson and Taylor (2002) produced a guide for iinanga habitat restoration and noted that marginal, emergent and aquatic vegetation were key components of iinanga habitat. Richardson (2002) showed that iinanga abundance declined dramatically in a small stream after all marginal and instream cover was removed. It follows that restoration of such marginal, vegetative cover, especially in small streams where bank vegetation is now limited to pasture, will improve iinanga habitat and therefore increase the abundance of this species.

Spawning habitat for iinanga along the main river stem has also been lost as a consequence of changes in riparian vegetation related to farming practices (Hayes, 1931; Mitchell, 1990). This is believed to be one of the main limiting factors for whitebait in the Waikato River (Stancliff et al., 1988; Baker and James, 2010), but the loss of adult habitat may be more significant. Spawning habitat is a life history choke point for iinanga in most rivers because it is confined to a relatively short length of river/stream bank above the influence of salt water intrusion but below the upper limit of tidal influence on river water level. Within this restricted length of river, egg-laying habitat currently occurs over short reaches of streambank with a shallow slope and the types of marginal, low-growing vegetation that have a thick matrix of stems close to the ground (Taylor, 2002). Iinanga spawning habitat is therefore limited in most rivers and is highly vulnerable to changes in channel morphology and bankside vegetation related to human activities (e.g., flood protection works, stock access).

Reports of iinanga spawning in historic times indicated that in many rivers it occurred on a large spatial scale within the area of the river affected by tides. Eggs were laid in salt, brackish and freshwater over a wide range of vegetation types (McDowall, 1984) suggesting that when adult numbers are very high, even suboptimal spawning habitat was used. In 1989, there were large amounts of intact spawning habitat in the Waikato River that were sparsely used (Mitchell, 1990). This situation is unlikely to have changed greatly since then, as the vegetation on the islands and swampy margins of the river is still intact. This suggests that adult habitat rather than spawning habitat may now be limiting. If so, an increase in habitat for adult iinanga may be more beneficial and important for fishery restoration in the Waikato River than the restoration of spawning habitat. However, in the absence of information to confirm this, restoration of both adult and spawning habitat for iinanga is required.

Restoration of the whitebait fishery in the Waikato will therefore depend on an increase in both the stream and lake habitat required for the growth of juvenile iinanga to adulthood (i.e., adult habitat), and an increase in spawning habitat. However, as noted above, an improvement in the habitat for banded kookopu could add to this. In the first and second order streams in hill country, the main change affecting the habitat of the banded kookopu has been deforestation and loss of the tree canopy over the streams. Cheyne (1981) indicated that c.1840, the area of indigenous forest in the Waikato River catchment at altitudes lower than 300 metres was 352.3 square kilometres, and that this was 67 percent of the original cover present. However, by 1976 forest cover had been reduced to 57 square kilometres, or 15 percent of the original cover. This impact will have been compounded by the subsequent loss of instream cover habitat that was once provided by fallen logs from the forested stream margins and which no longer occurs. Provision of more adult habitat for banded kookopu would therefore help improve the whitebait fishery. It would also deliver significant co-benefits for downstream water quality in the river and for the proliferation of a wider range of other native species.

Although full restoration of habitat for iinanga and banded kookopu in the Waikato River would result in a larger population of adults in the river, the increase in adult fish numbers would not necessarily guarantee an increase in the whitebait entering the river and contributing to the fishery. This is because juvenile whitebait that enter the Waikato River from the sea come from a 'marine pool' of fish that includes those from other west coast North Island rivers. Full restoration would require the return of all waters in the Waikato River to their natural state plus all waters in other west coast North Island river catchments potentially from Northland to Taranaki (see Figure 2). Furthermore, although restoration of riverine habitat for whitebait will increase the number of larvae in the marine pool, large natural fluctuations in whitebait catches occur between years as a result of marine factors affecting larval survival at sea such as food availability, water temperature, predators and currents (Rowe and Kelly, 2009). At present, there is little understanding of such natural variability, consequently it is not possible to quantify the response of whitebait fisheries to river-based management actions. This aside, restoration of whitebait habitat in the Waikato River would increase the resilience of the fishery to future changes (e.g., effects of climate change on freshwater and marine habitats) and it would increase the probability and frequency of higher catch rates.

A significant decline in kookopu harvesting in the upper Waikato River catchment, particularly in the river and streams below Lake Taupoo and mostly above Aatiamuri was also noted by iwi during the consultation phase of the Study. The upstream migration of tuna (and hence all other fish species) in the Waikato River was historically blocked by a chute and/or rapids near Maungatautari (Hawes et al., 1998). As a consequence, the kookopu caught in the catchment above this point will have been adult kooaro from Lake Taupoo. An abundant, landlocked population of this whitebait species occurred in both Lake Taupoo and Lake Rotoaira in pre-European times, with these lakes acting as an inland sea for the development of larvae to the whitebait stage (Rowe, 1993; Rowe et al., 2002). Movement of larvae and older fish down river will have continuously populated the upper reaches of the Waikato River and given rise to the kookopu historically harvested there. However, with the introduction of trout and then smelt, the kooaro population in Lake Taupoo declined to the point where this species is now rarely found in the lake and is confined to a few small inlet streams (Rowe, 1993). This decline, which started around 1900 and was completed by 1950, means that the upper Waikato River and its tributary streams are no longer colonised by kooaro from Lake Taupoo and this recruitment failure will have resulted in the decline of kookopu harvesting there. As the introduction of trout and smelt to Lake Taupoo cannot be reversed, the restoration of kookopu in the upper Waikato River and its tributary streams is no longer possible, unless kooaro are grown in a hatchery and then stocked into these waters.

Given that restoration of the whitebait fishery in the Waikato River needs to focus on increasing the stocks of iinanga and banded kookopu, viable actions related to river restoration need to be identified that will address the four approaches listed below.

- Restore iinanga spawning habitat on river and streambanks and create new habitat.
- Restore adult iinanga habitat in both streams and lakes.
- Restore access to iinanga and banded kookopu habitat.
- Restore adult banded kookopu habitat in small, tributary streams.

These approaches are based on current expert knowledge of the main limiting factors known to affect whitebait stocks in the lower Waikato River. As such, other approaches including a reduction in predation pressure (e.g., by trout), an increase in food supply, a reduction in competitors (e.g., pest fish), or the use of hatchery-based production of iinanga larvae, or fishery management, are not addressed here. These other approaches are all still largely hypothetical and dependant on more investigation and research (see Appendix 8: Fisheries Research) to determine both feasibility and viability in the Waikato River (see Appendix 7: Fisheries Management).

2. Goals for restoration

Actions that address the four approaches noted above will collectively help restore the whitebait fish stocks in the Waikato (and hence the fishery) and will be achieved if the following three goals are met:

- A significant increase in the area of spawning habitat used by iinanga is created in the lower Waikato River.
- A significant increase in the area of adult habitat occupied by iinanga in summer months is created in the lower Waikato River catchment.
- A significant increase in adult habitat occupied by banded kookopu is created in the lower Waikato River catchment.

In the following Section, the actions required to achieve these three goals are identified.

3. Actions

3.1 Restore iinanga spawning habitat

Riverine spawning habitat has been lost along the banks of the Waikato River because of inappropriate vegetation management (e.g., drainage and allowing stock access). Both Mitchell (1990) and Hayes (1931) noted the negative impact of stock access and grazing on iinanga egg-laying habitat in the Waikato River and Baker and James (2010) have noted the need to restore both adult and spawning habitat in the river. As spawning habitat for iinanga is very limited in rivers and is therefore a choke point in the life history of iinanga, restoration of spawning habitat in the Waikato River is clearly required.

The precise location(s) and boundaries of the spawning areas used by iinanga in the Waikato River are not well known despite extensive surveys by both Hayes (1931) and Mitchell (1990). Their observations indicated that iinanga spawned on the riverbank and on some streambanks between the elbow and the Okahu Stream (Maioro Bay) (Figure 3). In the Okahu Stream, spawning occurred some 300 metres above its junction with the main stem, probably because the river here is subject to periodic exposure to saline water. Above this stream, Mitchell (1990) found egg-laying sites only on the true left side of the river and many of these were associated with inlet streams. Iinanga spawning was also reputed to occur historically on the true left bank around the Aka Aka/Otaua region (Stancliff et al., 1988), but this was when a substantial river channel occurred down the true right side. Hayes (1931) also found some spawning sites on the islands in midstream.

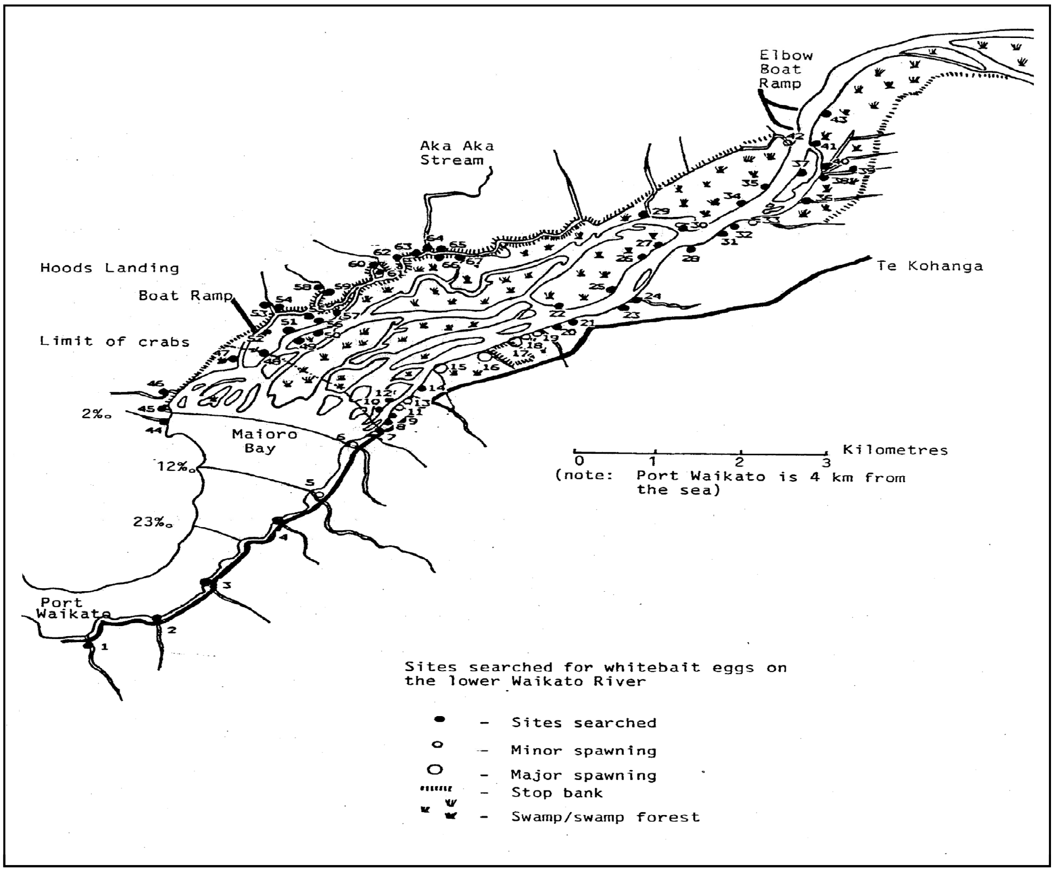

Figure 3: Map of lower Waikato River showing sites examined and found to contain iinanga eggs (Mitchell, 1990).

The total length of potential spawning habitat on the true left bank was assessed by examining the NZMS260 topographical maps and identifying areas where pasture has replaced wetland and native vegetation. There are approximately 10 kilometres of habitat on the true left bank (from the Elbow to Okahu Stream) of which 4.5 kilometres of wetland below Tauranganui are still relatively intact. On the true right bank, spawning habitat includes approximately three kilometres below the elbow and three kilometres on the side of Motutieke Island. Historically, spawning also occurred along the true right bank of the river around the Aka Aka/Otaua region, but this was when the main channel ran down that side of the river and before flood control structures were installed. Historically, some 30 kilometres of river and stream bank could have been used for spawning but only about 20 kilometres of this would have been used at any one time, depending on which side of the river the main flow occurred. At present, there is a total of 16 kilometres of riverbank within which iinanga can and do spawn. Of this, 5.5 kilometres are likely to require some degree of restoration. Restoration of iinanga spawning habitat along riverbanks in the Hawkes Bay (Rook, 1994) and in most Department of Conservation conservancies (Taylor,

2002) has been successful and an experiment to create new off-channel spawning habitat is now being carried out in the Waikato River to test this concept.

Fencing is relatively straightforward but maintaining the right vegetative cover for spawning is the key to success. The weed *Trascandentia* provides good spawning habitat under a cover of alder trees, but other more suitable ground cover plants include creeping bent, Yorkshire fog, tall fescue grass, Mercer grass, cow parsley, and creeping buttercup (Taylor, 2002). Historic (pre-European) plants are likely to have included rushes, raupoo (bullrush), harakeke (flax), toetoe and koikoi. Annual maintenance of the areas will be required to maintain an optimal vegetative cover during the spawning season (i.e., February–June). Hickford et al., (2010) found a strong correlation between iinanga egg density and the thickness of the aerial root mat and/or density of plant stems, irrespective of plant species. Vegetation management therefore needs to maximise stem and aerial root density, while allowing fish access to this egg-laying habitat.

The role of floodgates in restricting iinanga access to riverine spawning grounds is not well understood at present. Taylor (2005) found that iinanga spawned behind the tide gates on the Styx River (Christchurch) where suitable habitat occurred but not below the gates because habitat was lacking there. However, spawning did not occur every year and the gates may have resulted in a change in salt water penetration upriver that affected the location of spawning sites as well as the cues for spawning. Spawning habitat for iinanga occurs below most floodgates in the Waikato River but free passage is required to access this. If this cannot be achieved, then spawning habitat above the floodgates would need to be created.

The three main actions designed to restore and increase the iinanga spawning habitat in the Waikato River are listed below:

ACTION A:
• Delineate the main areas currently used for iinanga spawning on the true left bank of the main stem of the river and exclude stock access (at least before and during the iinanga spawning season i.e., January to June) while providing and maintaining suitable vegetation for iinanga spawning.

ACTION B:
• Identify iinanga spawning habitat along the banks of accessible tributary streams of the river and exclude stock access (at least just before and during the spawning season i.e., January to June) while establishing and maintaining suitable vegetation for iinanga spawning.

ACTION C:
• Create new off-channel areas (embayments) for iinanga spawning along the riverbank to compensate for loss of spawning habitat elsewhere. This approach may also need to be extended to the streams behind tide gates in the Aka Aka/Otaua region where spawning areas could be created. However, this would only be required if the tide gates currently restrict access to spawning sites on the main river and if this cannot be fixed.

3.2 Restoration of adult iinanga access to stream habitat behind flood control works

Migrant iinanga heading downstream to spawn generally stay in the main river channel which, in the Waikato River, now runs along the true left bank. This is where spawning occurs today and the absence of spawning on the true right bank of the river (i.e., around Aka Aka/Otaua) may be because there is no longer a major river channel along this side of the delta. However, the lack of spawning on the right bank may also be because iinanga access to it is currently restricted by tide gates, pumping stations and flood protection works. Structures that may restrict iinanga passage between the river and upstream habitat are centred mainly around the Aka Aka/Otaua region (Figure 4), but also include gates on low-lying land as far upriver as Mercer.

Iinanga are relatively common upstream of some of these gates (but not others) and good adult habitat is still present in the drainage network that has now replaced the once extensive wetland. It is apparent that juvenile iinanga can enter some of these streams (e.g., at times when the gates are open) and therefore produce a population of adults upstream. But passage past some gates is restricted. Strickland and Quarterman (2007) also found variation in iinanga passage upstream to habitat behind tide gates. This depended on individual gate characteristics, especially those that lead to high water velocities. At present, the Study team are not able to identify which of the Waikato gates present problems for juvenile passage upstream and which do not.

Spawning migrations from adult habitat above gates downstream to the Waikato River are less likely, especially if they need to occur in the few hours just before spring high tides (when the gates are mostly closed). If both juvenile migration upstream (between July and November) and adult iinanga passage downstream (from March to June) can be facilitated past these obstructions, then the potential spawning habitat along the true right side of the river would in all probability be used by these fish and the stocks currently above the floodgates would contribute more significantly to the Waikato River fishery.

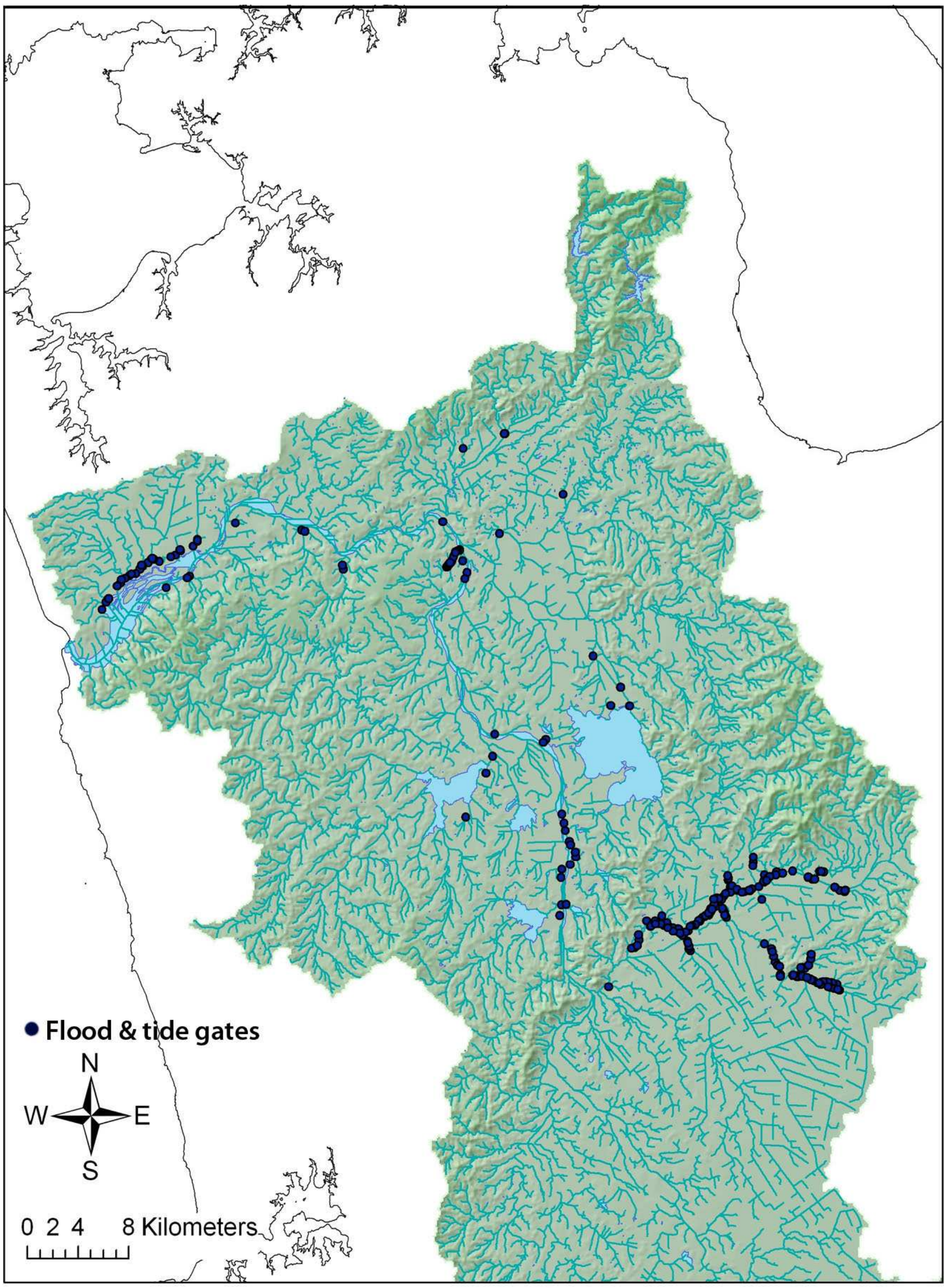

Figure 4: Location of known flood and tide gates in the lower Waikato River (data from Environment Waikato).

Models of habitat use for iinanga have been developed that allow streams providing good habitat to be mapped (Leathwick et al., 2005). In the Waikato River, this model indicated that its predicted occurrence at a 0.5 probability level corresponded closely with its actual occurrence. The total length of stream habitat in the Waikato River that has a probability of occurrence of over 0.5 is close to 800 kilometres (Figure 5). Approximately 320 kilometres (40 percent) occurs in catchments below the confluence of the Mangatawhiri River and the Waikato River. This is prime habitat for iinanga because it is closer to the river mouth than habitat further upriver. Of this, 192 kilometres (24 percent of total iinanga habitat) are behind the floodgates and therefore potentially affected by flood protection works and road culverts (Note, this figure does not include the side drain networks so actual iinanga habitat may be even greater).

Restoration of full access for iinanga between upstream habitats and the main river would require either removal of the tide (and flood) protection barriers, or the provision of access at key times (i.e., during the juvenile migration season and the spawning season). Removal of these structures and allowing the land to revert to wetland would restore a large area of lost wetland in the lower Waikato and the probability that this will increase whitebait habitat is high.

ACTION D:
• Remove all tide gates and stop banks in the lower Waikato River region (e.g., Mercer down to Aka Aka/Otaua) to restore wetland habitat and to allow unrestricted access by iinanga between riverine spawning habitat and stream habitat for adults.

There is a significant risk with this action. Rowe et al., (2007) recorded the negative impact of gambusia on iinanga in shallow waters and concluded that gambusia can exclude iinanga from the shallow (up to 50 centimetres), still-water habitat provided by swamps and wetlands. Gambusia are now present and widespread in the Waikato and can be expected to prevent iinanga from fully occupying and using existing and new wetland habitat, apart from the deeper (deeper than 50 centimetres) ponds and accessways. Restoration of wetland habitat (via removal of tide gates and flood control structures) may therefore no longer be a feasible option to restore iinanga habitat and hence the whitebait fishery.

An alternative to total removal of the flood control structures would be the installation of fish-friendly gates. These would allow greater immigration of juveniles from the river to the drainage network. If they can also be managed to allow emigration of adult iinanga to the river to spawn, they could significantly improve the fishery. At present there is insufficient knowledge on the timing of downstream iinanga migration in these streams to quantify the feasibility of this approach.

Although fish-friendly gate openers will allow adult iinanga to move downstream to the river at times, movement at the time required for spawning may not be possible. If this proved to be so, then the only remaining option is to create/improve spawning habitat for iinanga behind the floodgates (see Action C above).

ACTION E:
• Retrofit tide gates with fish-friendly openers to improve iinanga movement between the river and the drainage network (this may also improve adult habitat behind the gates).

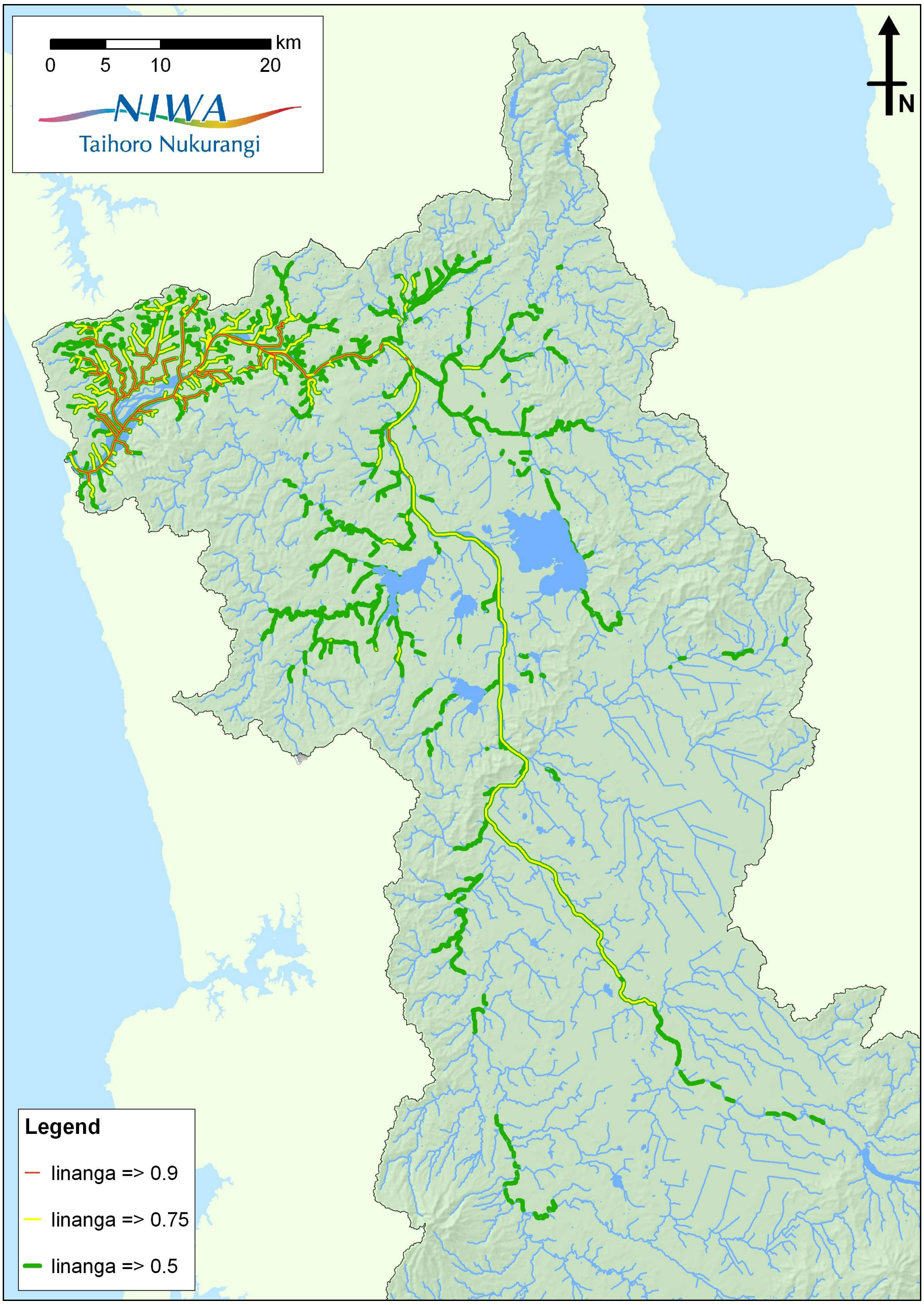

Figure 5: Location of stream habitat for iinanga in the Waikato River based on habitat models (Leathwick et al., 2005) and probability of occurrence. Prime habitat is marked red, optimal yellow, and good is green.

3.3 Restoration of adult iinanga to stream habitat

Loss of iinanga habitat in the Waikato River catchment has occurred in streams firstly, because iinanga access to it has been restricted by the installation of road culverts that create barriers to upstream movement of juvenile migrants. Secondly, stream habitat has been generally degraded because of channelisation coupled with a reduction in marginal riparian vegetation (i.e., important instream cover habitat for iinanga).

Replacement of all culverts that are a barrier to iinanga with larger diameter culverts that form an overarching, bridge-like structure is potentially possible and the best option, but would be expensive. In lieu of this, retrofitting culverts with baffles to reduce water velocities can work well but is only feasible in the larger culverts (greater than one metre diameter) such as occur under roads and which can be entered by workmen. Road culverts that intersect streams providing optimal habitat for iinanga are shown in Figure 6. At some sites, where the downstream lip of the road culvert is above the stream water level, a concrete and rock ramp will be needed to allow iinanga access up to the lip of the baffled culvert. Creation of a pool below the culvert (e.g., by placement of rocks to create a natural rapid) can also raise the steam water level above the lip of the culvert.

Retrofitting of baffles is not feasible in the smaller culverts under farm tracks. In general, many more farm tracks cross streams than roads and the culverts under farm tracks are usually smaller than those under roads. As a consequence, farm track culverts usually create a greater barrier for iinanga than road culverts. They should ideally be replaced with larger diameter ones positioned to act as bridges (i.e., the stream substrate runs through them).

Jones (2008) carried out a survey to identify which culverts posed a barrier to native fish in selected Waikato River catchments. She selected catchments with an area of approximately 100 hectares and identified all culverts upstream. Most culverts (99 percent) were concrete pipes and the number per 100 hectares catchment ranged from zero to 10, with a mean of 3.6. Of all the culverts inspected, 60 percent were a barrier to fish at most flows and 36 percent at all flows. The latter will have been primarily perched culverts and affected upstream migration of climbing species (i.e., banded kookopu) as well as iinanga, whereas the former will have provided a restriction mainly for iinanga.

ACTION F:
• Restore iinanga access to adult habitat by retro-fitting baffles to road culverts that are a barrier to iinanga and by replacing farm track culverts that are a barrier to iinanga with fish-friendly designs.

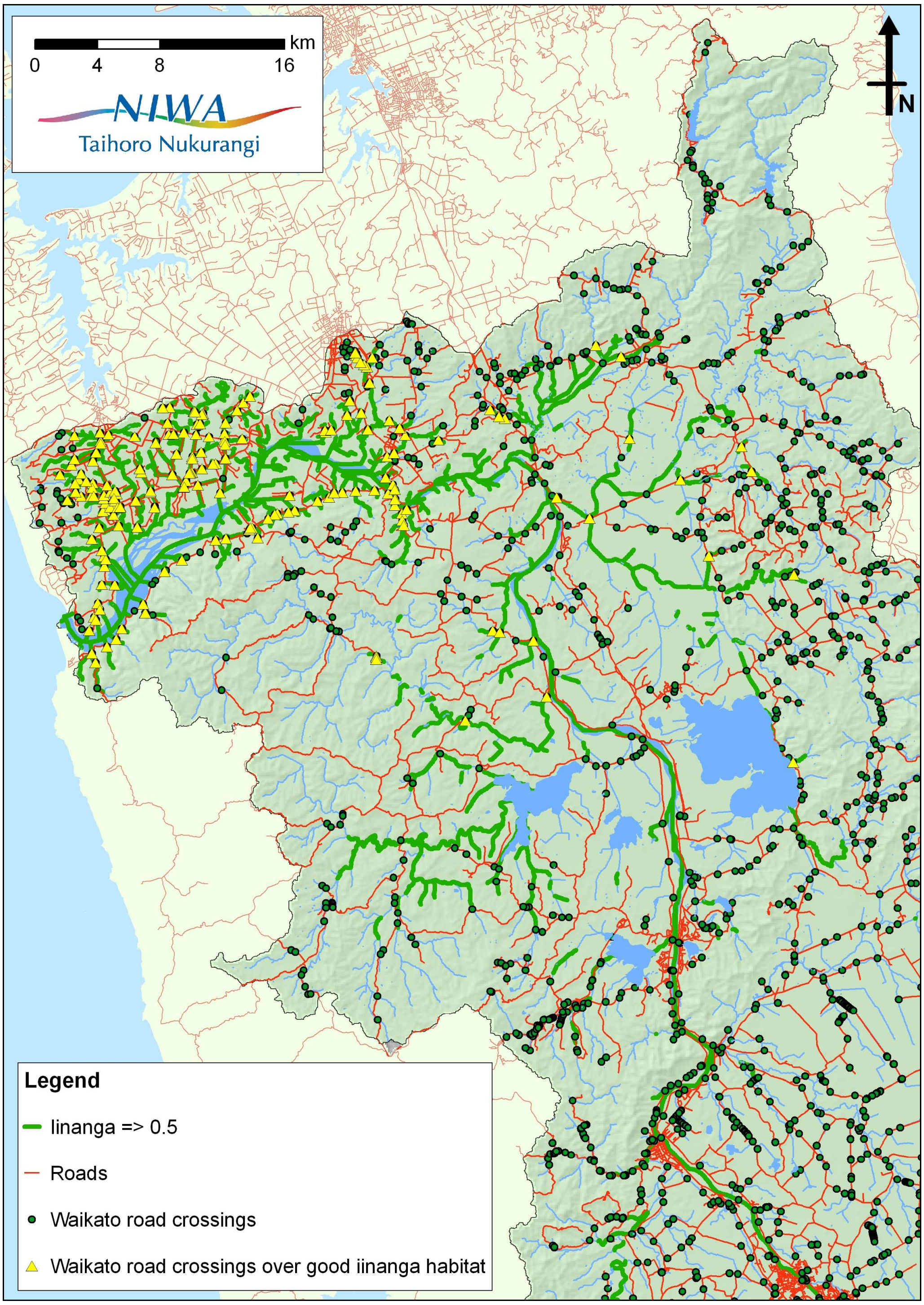

Figure 6: Map showing the intersection of streams and roads in the lower Waikato River and hence where culverts may occur (Note some streams will be crossed by bridges). The yellow triangles cross streams providing good iinanga habitat as identified by modelling.

Iinanga habitat in small first to third order streams is generally slow-moving to still waters with marginal stream cover provided by overhanging shrubs (e.g., harakeke), emergent vegetation (e.g., watercress, rushes) or aquatic macrophytes (Richardson and Taylor, 2002). This marginal cover is closely related to adult abundance

(Richardson, 2002) and most of it will have been lost through cattle browsing to the stream edge, coupled with the deepening and narrowing of the stream channel in response to the replacement of riparian forest cover with pasture, and erosion of the stream bank.

Restoration of stream habitat for iinanga in such streams would require the creation of riparian strips along the borders of those streams that currently run through pasture. Iinanga are not as abundant in heavily shaded streams (i.e., with total canopy closure) as they are in more open streams. Planting of low-height trees/shrubs (not causing total canopy closure) would be required to stabilise and partly shade the banks of second and third order streams. Low-lying vegetation that overhangs into the water (but which does not clog the stream channel) would be required in first order streams.

ACTION G:

- Restore adult iinanga habitat in lowland streams by ensuring that low-lying marginal plants (e.g., native flaxes, grasses) are present and can hang over the bank into the stream[2].

Beentjes (2005) estimated that there are 3,460 kilometres of managed waterways in the Waikato River catchment. Many of the smaller managed streams (and drains) occur in flat or low-gradient areas of the lower Waikato River and provide good potential habitat for iinanga. However, these streams and drains are now regularly clogged with vegetation during summer months. Iinanga enter rivers as juveniles in spring, migrate into small streams and grow to adulthood over summer, and then spawn in autumn. Summer is therefore a key period for iinanga production and such small streams are a major habitat. Some of these waterways are mechanically cleaned (by drainage boards) in order to maintain a flow and reduce flood risk, but this is detrimental to fish (and fish habitat). A more appropriate solution would be to shade the northern sides of such streams to prevent macrophyte weed growth and to maintain a low vegetative cover in other reaches by physical removal and or herbicide application.

ACTION H:

- Restore adult iinanga habitat in lowland, low gradient streams by shading (tree planting) physical reduction and herbicide application to reduce macrophyte weed growth.

[2] This approach can be expected to work well where the streambanks are low and not incised and needs to ensure that species such as blackberry and toetoe do not smother the stream.

3.4 Restoration of adult iinanga habitat in lakes

McDowall (1984) observed that wetlands were a crucial habitat for iinanga and argued that the decline of whitebait in New Zealand was in large part attributable to the large reduction of this habitat throughout the country. Loss of wetlands in the Waikato River has been substantial with Cheyne (1981) noting an 83 percent loss between 1840 and 1980 – this figure will now be higher. This loss of habitat coincided with a significant decline in mean catch rates in the Waikato. In a review of the fishery, Stancliff et al., (1988) concluded that there was a 70 percent reduction between 1950 and 1968. At the same time, iinanga access to the large lakes (Whangapee, Waikare and Waahi) was restricted by flood control works. Although access has now been restored, the lakes subsequently lost their macrophyte beds and in more recent times have become infested with pest fish which help degrade water quality, prevent macrophyte re-establishment and may compete with native fish for food (Rowe, 2007). The effects of such environmental changes in the lakes are reflected in the low abundance of iinanga. For example, in Lake Waahi the abundance of iinanga is now only two percent of that in Lake Ellesmere/Waihora (Rowe et al., 2007) which lacks pest fish.

The precise reason(s) for the decline of iinanga in the Waikato lakes are unknown. Competition for food with other fish may be the main factor, or there may now be greater predation on iinanga because of the loss of macrophytes. Alternatively, food for all fish may have declined because of a decline in water quality. In the absence of data on the specific habitat and food requirements for iinanga in these lakes, restoration of iinanga abundance will require full lake restoration. In the absence of full restoration, some habitat improvement in the lakes may be possible and could include the placement of log jams or batten-style fences in the lake at strategic locations designed to damp wave-action and encourage macrophyte growth. However, this approach is untested and would require some research to determine its viability. It is therefore not included as an action at present. In lieu of this, shallow, static water habitat for iinanga needs to be maximised wherever possible in the lower Waikato River (especially below Mercer). Where ponds or quarry pits or other depressions occur and could provide such habitat for iinanga, access needs to be created if possible.

ACTION I:
Restore iinanga habitat in the riverine lakes through removal of pest fish species. Increase the amount of still-water habitat (ponds, pits, quarries, artificial impoundments) for iinanga in the Waikato (this implies the development of fishways that allow iinanga access but not pest fish).

3.5 Restoration of habitat for banded kookopu and other whitebait species

Banded kookopu live in the pools of small, low-gradient first order streams where a tree canopy occurs and shades the stream (Rowe and Smith, 2003). It does not matter whether the tree canopy is native forest, bush or pine forest, as banded kookopu abundance under any canopy is significantly higher than in pasture streams (Rowe et al., 1999). Much of this habitat for banded kookopu in the Waikato has been lost because of the clearance of forest to create pasture. However, there are 308 kilometres of stream in the lower Waikato that potentially provide optimal habitat for banded kookopu (Figure 7). Of this, 58 kilometres have a low shade index indicating a lack of tree cover.

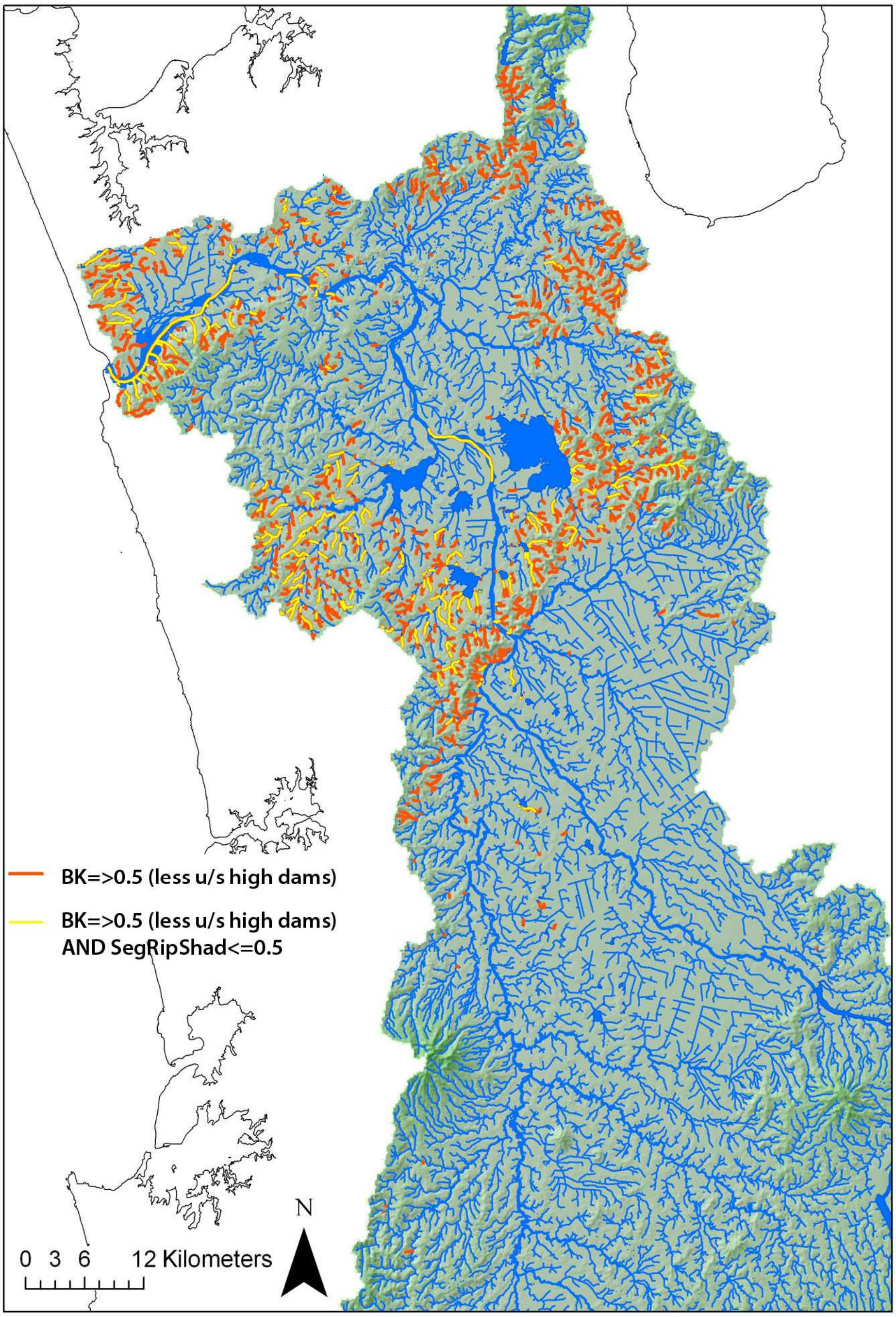

Figure 7: Location of good stream habitat for banded kookopu (BK) in the Waikato River as determined by modelling and the reaches within this where shade cover is sparse (yellow) versus abundant (red).

Cover aside, access to some of the streams providing good potential habitat may now also be prevented by perched culverts. Fencing and tree planting along the banks of small streams will restore habitat for banded kookopu and benefit other whitebait species (e.g., kooaro, giant kookopu, shortjaw kookopu) and native fish. It will also reduce stream bank erosion, cool stream water and reduce both nutrients and bacterial contamination. Significant co-benefits of riparian planting will therefore occur from the restoration of banded kookopu habitat in small, hill-country streams.

ACTION J:
• Identify the stream reaches providing potential habitat for banded kookopu and plant with perennial trees to provide riparian cover (heavy shade) over the stream channel.

ACTION K:
• Identify where perched culverts prevent access to good habitat for banded kookopu and install ropes (or concrete ramp structure) to allow the climbing juveniles to access the stream habitat behind these culverts.

4. Outcomes

A significant increase in iinanga spawning habitat, and in the adult habitat for both iinanga and banded kookopu, can be expected to increase the production of fish larvae exiting the river and developing at sea. In turn, this will increase the number of juvenile fish (whitebait) entering the Waikato River and hence improve the fishery. The unknown dispersion of whitebait larvae at sea and the annual variability in marine conditions means that the benefit of restoration will be spread over a range of west coast North Island rivers and will not accrue solely to the Waikato. As a consequence, the actual benefit to the Waikato River cannot be quantified. Habitat restoration for iinanga and banded kookopu in the Waikato River will also improve river water quality and increase habitat for other native fish, so will result in widespread co-benefits.

5. Risks and probability of success

The risk of not being able to successfully achieve an action was given a high, medium, or low rating based on the complexity and scale of the action, the ability to control extraneous factors, current knowledge of the issues, and the technologies available (but not overall cost). The probability that the action, if achieved in full, will succeed in achieving the goals was also rated as high (H), medium (M), and low (L). These ratings were used to identify priority actions (i.e., those that are most feasible and which have a high probability of success) (Table 2).

Table 2: Assessment of the feasibility of achieving the respective actions and the probability of success should they be achieved

	Action	Feasibility	Probability of success	Comment on success for restoring whitebait
A	Improve current riverbank spawning sites on true left bank	H	H	Highly feasible so long as maintenance occurs.
B	Improve stream bank spawning sites	M	M	Full use by iinanga cannot be guaranteed.
C	Construct new spawning areas on true left bank streams	M	M	Full use by iinanga cannot be guaranteed.
D	Remove flood control structures	H	M	Feasible action, but full use of wetland habitat cannot be guaranteed.
E	Retrofit tide gates below stream spawning sites	H	M	Feasible, but may still not permit spawning migrations. Some flood and salinity risk likely.
F	Replace/fix culverts that are barriers to iinanga	M	H	Highly feasible so long as annual maintenance carried out.
G	Increase cover habitat in small streams	H	H	Low risk and highly achievable.
H	Reduce stream clogging by weeds	H	H	Low risk and highly achievable.
I	Restore lakes and/or provide access to man-made standing waters (ponds, pits, quarries)	L	M	Access for iinanga may allow pest fish in.
J	Fence and plant first order streambanks	H	H	High success rate but long time-frame for tree growth required.
K	Fix perched culverts affecting banded kookopu	H	H	Ropes easily installed. Periodic replacement required.

Actions A, F, G, H, J and K all have a high probability of success and a high to medium feasibility. Similarly, actions D and E have a medium probability of success but are highly feasible. In contrast, actions B, C and I are riskier in terms of both their feasibility and/or probability of success. They therefore require more information before they are implemented. All actions will require site-specific evaluation which is beyond the scope of this Report.

6. Costs

6.1 Action A: Restoration of riverine spawning habitat

Restoration of spawning habitat on the true left bank of the Waikato River would involve establishing a five-metre wide riparian strip adjacent to the water's edge along much of the 10 kilometre length of riverbank, excluding the c.4.5 kilometre length of wetland below Tauranganui. In other words, there is a 5.5 kilometre length of riverbank within which management is required to restore iinanga spawning habitat. Cattle access would need to be excluded, at least from December to June each year, to allow riparian grass growth, but management would be required to ensure growth is not excessive resulting in impeded access. This option provides for partial grazing controlled by electric fencing, within which vegetation management would be required. Total cattle exclusion would require a post-and-batten fence and planting to ensure that low-growing native plants with moderately dense stem and/or root matrices are grown beneath a sparse tree cover.

The costs involved in this action include a survey to locate sites for restoration and to prepare fencing and planting plans for each. This preparation phase would also require consultation with land owners to determine compensation (for lost pasture use), and to ensure access for maintenance. Fencing and planting would then follow. The capital cost for land purchase, fencing (permanent fence) and planting is estimated at about $260,000, whereas use of an electric (temporary) fence would reduce this to $90,000 (less if farmers can use the land as pasture for six months of the year). Annual maintenance of approximately $22,000 would be required for 10 years.

6.2 Action B: Restoration of stream-bank spawning habitat

Eight streams enter the main river between the Elbow and Okahu Stream. Spawning occurs at a site 300 metres upstream in the Okahu, possibly because of high salinity water near its confluence with the main river. The area of potential and actual spawning habitat in each stream is unknown but there is scope for improvement in at least some of these streams. For the purposes of costing restoration of spawning habitat in these streams, the Study team have assumed that there is a 50-metre long length of potential spawning habitat to be restored on each bank (i.e., 100 metres per stream). Cattle access and vegetation management would be required at each site. The capital cost for this action (excluding site surveys and plan preparation, but including land purchase) is estimated at $280,000, with an annual maintenance cost of $3,200 for 10 years..

6.3 Action C: Creation of new iinanga spawning habitat

New, off-channel, spawning habitat could be created within the eight inlet streams on the left bank of the main stem of the Waikato River. This would involve the creation of artificial embayments and/or side channels with gently sloping sides that would provide a relatively wide (one metre) wetted margin of relatively flat ground covered in suitable egg-laying vegetation. The height of this needs to be set so that it is inundated only during spring high tides in autumn. A pilot study is currently underway to test this concept in the Whauwhautahi Stream, which is one of the eight streams along the true left bank. At present, this approach is being tested and some spawning has occurred within the 500–700 metres of new habitat. On this basis, 500 m of new spawning habitat could be created in each of eight more sites to add another four kilometres of potential spawning habitat to the lower Waikato River. The capital cost for this action including plan preparations and consents is estimated at $4.2 million, with an annual maintenance cost of $32,000.

6.4 Actions D and E: Restoring full access to streams affected by tide gates

Removal of tide gates from the elbow down to Maioro sands is one option to allow iinanga full access between the river and streams. This action (Action D) would improve iinanga access to the stream network provided by the five main streams entering the river in this region (i.e., Mangawhero, Aka Aka, Awaroa, Otaua and an unnamed stream west of the Otaua). More significantly, it would allow adult iinanga access to riverine spawning habitat. However, it would also result in a large expanse of farmed land (approximately 55 square kilometres) becoming periodically flooded. At present 23 flood control gates occur in this region. Removal of all these flood protection works in the lower Waikato River would have major impacts on land use. The capital cost of this action is estimated to be in the order of $220 million, with land purchase being the major component. Removal of a fewer number of gates is unlikely to be feasible as the entire area is low-lying and removal of just one gate would risk widespread flooding.

In lieu of this action, another less disruptive option would be to replace the tide gates with fish-friendly ones that will allow juvenile iinanga better access to the stream habitat behind them and allow adults to migrate down to the river to spawn (Action E). This would not be as effective for fish access as removing the gates, but it may be a more cost-effective option than complete removal. At present there are 23 sites where tide gates occur in the Aka Aka/Otaua region but the number of gates per site varies. Replacement of one gate per site where the number of gates is high (greater than two) is not expected to be hydrologically feasible, so on average there would be two gates to replace per site (i.e., 46 in total). Of the 23 sites, five are likely to be more important than the others as they affect access to and from the main streams, but they contain multiple gates. Prioritisation is therefore possible. In addition, there are another eight gates across streams entering the true left bank of the Waikato River below the Mangatawhiri River confluence. The total cost of installing 23 fish-friendly tide gates is estimated at $6.9 million.

6.5 Action F: Culverts acting as barriers to iinanga passage in streams

GIS (geographical information system) analysis indicates that the streams providing good habitat for iinanga in the Waikato are crossed by approximately 180 road crossings. The study by Environment Waikato (Jones, 2008) indicated that 60 percent of inspected culverts (including road culverts) restricted passage for fish such as iinanga. Accordingly about 110 road culverts can be expected to require retrofitting with baffles. Of these, approximately half (i.e., 55) can be expected to also require either the construction of an inclined approach ramp below the culvert (i.e., made of rocks embedded in concrete), or the installation of a boulder weir (some five to 20 metres downstream) to create a pool behind the culvert. This will raise the water level over the lip of the culvert and allow fish passage upstream. The cost of retrofitting 110 road culverts to allow passage for iinanga is estimated at $2.4 million, with an annual overall maintenance cost of up to $110,000.

The number of farm track culverts that would need to be replaced can be estimated by using the data provided by Jones (2008). She found that there was an average of 3.6 culverts per 100 hectares of catchment in the Waikato River region. Of these 60 percent (i.e., 2.16 culverts/100 hectares) were judged to be a partial barrier to fish such as iinanga. When this figure is multiplied by the total area of catchment in which good iinanga streams occur (approximately 1,500 square kilometres) there are in the order of 3,000 farm track culverts that could need replacement. The total cost for replacing each of these culverts would be in the order of $30 million. Not all of these culverts will contain large areas of iinanga habitat upstream and therefore constitute a high-impact priority for replacement. A comprehensive site survey would be required to identify the high impact culverts and therefore allow prioritisation of this action (i.e., allow a more targeted approach that ensures best value for minimum cost).

6.6 Action G: Restoring cover for iinanga in streams

The total length of potential stream habitat for iinanga in the Waikato River is estimated to be close to 800 kilometres and of this 150 kilometres comprises first order stream habitat where low-growing marginal cover is important for iinanga. There is a further 300 kilometres of second and third order stream habitat where a riparian strip comprising both sparse tree cover and shrubs would be required. Thus, 450 kilometres of potentially optimal stream habitat could be restored. This action would initially require a foot survey to identify sites where fencing and riparian planting will be most effective and to determine restoration plans for each stream reach. The Fonterra 'Clean Stream Accord' is expected to eventually result in many small streams being fenced and this alone will allow some natural regeneration of low-lying vegetation on streambanks to occur. However, in many cases this may result in rampant blackberry covering small streams, or toetoe and emergent species clogging the stream channel. Strategic planting of one side of the stream with more suitable low-lying species is therefore required. The cost of such planting (assuming fencing costs are borne by farmers as a consequence of the Clean Stream Accord) is estimated at $2.9 million. Annual maintenance ($360,000) for up to at least five years would be required on top of this. If an action for farming is to fence and plant streams, then these costs will be met by the farming industry.

6.7 Action H: Reducing excessive weed growth in streams

It is not known what proportion of the 3,460 kilometres of managed waterways in the lower Waikato River require summer vegetation control in order to provide open-water habitat for iinanga. For the purposes of costing, the Study team assumed that about 50 percent of these waterways (i.e., 1,800 kilometres) could require some form of weed management. Methods currently used for control of instream vegetation include mechanical removal (by digger), herbicide application and biological control using white amur (*Ctenopharyngodon idella*[4]). However, tree planting on northern banks to provide heavy shading of the stream channel could provide a long-term sustainable control in some reaches. As not all stream reaches will be suitable for tree planting on the northern side, other vegetation control methods would be needed. If it is assumed that 450 kilometres would be amenable to tree planting, some 450 kilometres could require biological control, 450 physical control (but not by a digger), and 450 kilometres herbicide application. Using these figures, it is possible to gain an indication of the cost of each method. The capital cost of tree planting would be $3.1 million, with $360,000 annual maintenance required for 10 years. If an action for farming is to fence and plant streams then these costs will be met by the farming industry. Biological control would cost around $3.0 million, with the annualised cost of on-going maintenance (e.g., restocking) at $120,000. Physical control (e.g., manual removal) can be expected to be in the order of $3.6 million per annum for at least 10 years and possibly in perpetuity. In comparison, herbicide control (assuming one application) would cost $180,000 per annum in perpetuity, but would not be acceptable if the herbicide affects other aquatic life. Given the high costs of physical weed control, a priority action is detailed site inspection to determine where shade control would be effective and where mechanical control is the only available option.

[4] This fish maintained total control over macrophytes for over three years in the Mangawhero Stream, Aka Aka but the trial was discontinued because of the escape of white amur into the Waikato River.

6.8 Action I: Restoring iinanga habitat in lakes and standing waters

Whitebait abundance has declined in the three main lowland lakes in the lower Waikato River (Waahi, Whangapee, Waikare) as their macrophytes disappeared and as pest fish increased and water quality declined. Restoration of macrophytes and water quality could be required, but this alone may not restore iinanga as pest fish are now prolific in these lakes in summer months. Restoration of iinanga abundance may therefore involve pest fish control as well as the return of macrophytes. There is also no known way of effectively controlling pest fish in large, shallow water bodies without also affecting iinanga. The decline of iinanga in these lakes is likely to be the single most important factor contributing to the decline of the whitebait fishery in the Waikato but identification of the key limiting factor(s) is a pre-requisite for successful restoration. For example, macrophyte restoration may be all that is required. However, if pest fish and not macrophytes are the limiting factor, it is unlikely that these fish will ever be controlled. Although removal may be feasible (e.g., by draining the lakes and Rotenoning the inlet streams), the next flood will re-populate the lakes. The restoration of these lakes (including removal of all pest fish) could be done through drainage, sediment excavation, levee formation to increase lake depth, and then refilling. If bunds or levees are built to prevent flooding, then iinanga access will need to be provided to the lakes and at present there is no way of guaranteeing such access without running the risk that juvenile pest fish will also use the same route to re-enter the lakes.

Pest fish re-entry would need to be restricted[5], but could be problematic if barriers to pest fish migration also exclude juvenile iinanga. Rowe and Dean-Speirs (2009) identified low-head barrier designs for pest fish species. They concluded that a number of designs could be used in the Waikato, but these would necessarily exclude iinanga as well as juvenile pest fish, unless they are designed to provide a shallow depth of water that allows upstream movement by juvenile iinanga and smelt, but not pest fish. Research is required to determine whether such a pass can be developed. This applies to the provision of access to other shallow water bodies such as quarry pits, opencast mines, irrigation ponds, farm ponds, etc.

6.9 Action J: Restoration of banded kookopu habitat in first order streams

Optimal habitat for banded kookopu generally occurs in the pools of small, elevated streams under a closed tree canopy and within a distance of 150 kilometres from the river mouth. Habitat modelling indicates that there is 308 kilometres of such habitat in the lower Waikato (excluding that currently restricted by the dams at Hunua). Of this approximately 60 kilometres (19 percent) has a relatively low shade cover (less than 0.5 kilometres) and so is likely to be suitable for restoration via riparian tree

[5] Research is required to determine whether pest fish are in fact limiting iinanga abundance in these lakes.

planting. Fencing and planting of trees alongside these stream reaches can be expected to increase the overall population of banded kookopu in the Waikato. The full ecological benefit of this will not occur until canopy closure occurs and this could take 10 or more years. The capital cost of this action is estimated at $4.1 million with annual operating costs of $240,000.

6.10 Action K: Restoration of banded kookopu access past perched culverts

Jones (2008) found that there were on average 3.7 culverts in each 100-hectare catchment inspected and that 36 percent of these were a barrier to fish at all flows. These will have been mostly perched culverts and therefore barriers to banded kookopu. The total catchment area in the lower Waikato River containing good banded kookopu habitat and where culverts affecting this species can be expected (i.e., first to third order streams) was summed for the individual sub-catchments and estimated at 1,116 square kilometres. Given that there are, on average, 3.6 culverts per square kilometre in the Waikato, the Study team estimate that there are around 4,000 culverts of which 36 percent or 1,440 would be barriers to banded kookopu and require rope passes.

Perched culverts can be readily accessed by migrant banded kookopu if a substrate with a wetted surface is provided. Small lengths of mussel spat collecting rope have been shown to be effective in addressing the problem posed by perched culverts (David et al., 2009). The length of rope is fixed to the lip of the culvert and cut so that its lower end is in the pool below. On-going annual maintenance would be required. As the migration of banded kookopu into rivers does not occur until September and extends through to November, ropes would need to be placed in culverts for the months September–December each year. The cost of completing this action was estimated to be $940,000.

7. Cost comparisons

Ideally cost comparisons would compare the dollar cost of an action against some measure of improvement in the fishery. As there is currently no way of assessing whether a change in the fishery is due to some management action in the river (as against a change in marine conditions influencing whitebait survival at sea), this is not possible. However, a surrogate measure of potential improvement in the fishery is the amount of habitat improvement that has been completed. In this case, it would be the length or area of habitat that is improved or created, or the number of culverts that are modified to allow fish passage upstream. Culverts can be prioritised, depending on the amount of habitat upstream, but this detail is beyond the scope of this Study. These numbers can be expressed as a percentage of the respective target levels to fit within the Report Card format for gauging progress over time.

Comparisons among the actions can be made on the basis of total cost. Table 3 shows the least to the most expensive action in terms of total capital and operational costs for whitebait restoration. Capital costs are assumed to occur in the first year (2011), whereas operational costs are occurring on an annual basis until 2040, unless specified differently. Capital and operational costs are discounted at eight percent to give the present value of costs[6]. Some costs will not change from the above as only capital costs are considered for that option and they are assumed to come in year 2011, therefore do not need to be discounted. The wide range for total costs indicates that some actions are unlikely to be economically feasible whereas others will be.

The total cost of an action can also be compared with the cost of a unit of action (e.g., a kilometre of habitat improved, or a single barrier to fish access fixed) to examine the feasibility of partial completion. Two approaches to this are illustrated in Figure 8. Actions D and H have a high total cost as well as a high unit cost. In contrast, actions A1, A2, and B all have relatively low total and unit costs. The latter are therefore more feasible in overall economic terms.

Table 3: Actions ranked by total cost to full completion

Action	Description	Total cost ($100k)
D	Improve iinanga access to 23 streams where flood control works create barriers (Aka Aka/Otaua).	2,202
H	Increase iinanga habitat through vegetation control.	435
E	Alternative to D is installation of fish-friendly tide gates.	69
G	Enhance iinanga stream habitat by planting low-lying species along 450 kilometres of streambank.	54
J	Restore kookopu habitat with a tree canopy over 58 kilometres of first order streams.	51
F/2	Replace 3,000 farm track culverts that are barriers to iinanga.	30
C	Create new iinanga spawning habitat at eight river sites.	30
F/1	Retrofit 110 road culverts that are barriers to iinanga with baffles.	27
B	Restore 800 metres of iinanga spawning habitat in streams.	3
A/1	Restore 5.5 kilometres riverine spawning habitat by fencing river margin (post and batten fence).	3
A/2	Restore 5.5 kilometres riverine spawning habitat by fencing river margin (electric fenced for four months per annum).	1
K	Replace 1,440 culverts that are barriers to banded kookopu.	1

[6] Present value is the value on a given date of a series of future payments, discounted to reflect the time value of money and other factors such as investment risk.

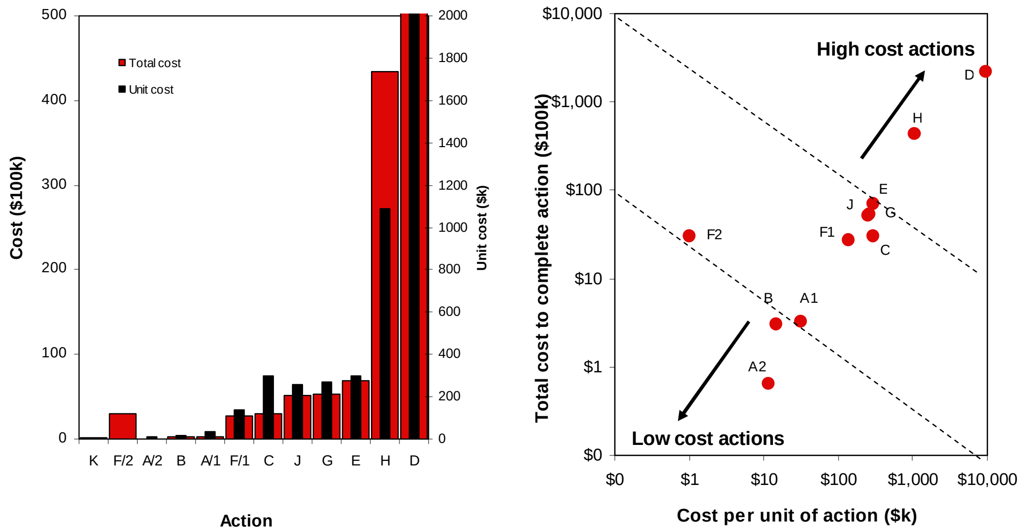

Figure 8: Comparison of the costs of each action based on both total (capital and operating) cost and the unit of action cost. In the right hand figure, the actions are plotted on logarithmic scales to encompass the wide variation in costs. The dashed lines separate actions with relatively high, medium and low costs for both total and unit cost.

8. Baseline/Monitoring restoration

The baseline for the Waikato River whitebait fishery cannot be established in terms of the size of the fishery or total catch, so needs to be measured in terms of habitat units. In this context, there are three types of habitat; iinanga spawning habitat, iinanga adult habitat (used for growth) and banded kookopu adult habitat. All three can be measured in terms of the metres or kilometres of stream or river potentially capable of supporting such habitat and the proportion of this total that is currently intact. The proportion that is not intact provides the basis for restoration and progress with restoration can be measured as this figure declines with time.

The total amount of iinanga spawning habitat has not been accurately quantified but patches of egg laying now occur over a 16 kilometre length of the riverbank. Additional spawning habitat occurs within some streams but the extent of this is unknown and it is probably limited to hundreds of metres rather than kilometres. When the main river channel went down the true right side of the river, spawning habitat would have been utilised there, meaning that in total 30 kilometres of spawning habitat occurs but only about 20 kilometres of this will be used at any one time, depending on where the main channel occurs. The current length of iinanga spawning habitat in the Waikato is therefore close to 20 kilometres and there is scope to produce another four kilometres through excavation of the streambanks and the creation of new side channels and embayments (even though the success of this is still to be demonstrated).

Adult whitebait numbers will increase if their habitat is increased or improved. The loss of wetland and lake habitat in the Waikato has already been noted as the major concern in the Waikato River, but its restoration cannot yet be guaranteed and restoration may not be possible in some cases. Research is required to determine this. Lakes and wetlands aside, restoration of stream and riverine habitats are possible and this can be measured in terms of the kilometres of habitat that is improved for iinanga (i.e., bankside vegetative cover is provided, stock access excluded). However, having good habitat does not guarantee that it is used, especially if iinanga cannot access it because of a downstream barrier created by a culvert. The measure of usable iinanga habitat is therefore the total amount (length) that is intact in terms of riparian vegetation and that is accessible. This will increase as the barriers created by flood control structures and culverts are reduced. Although maps of restorable stream habitat can now be produced (at a coarse scale), it is not possible to map the accessible versus inaccessible habitat. This is because the locations of the culverts that are barriers to iinanga (as against the overall estimated number of these) have not been identified yet. Nevertheless, it will be possible (in time) to identify which culverts are more important than others in terms of their impact on iinanga access to existing or restored habitat. Once this is achieved, it will be possible to map all streams in the Waikato and to determine the total length of those that provide both good habitats for adult iinanga as well as access to it. The difference between this figure and the measure of stream length that is either not restored yet or is intact but still not accessible will provide an index of progress with restoration.

Similarly, the amount of potential stream habitat for banded kookopu in the Waikato can be mapped and the proportion of this where a total tree canopy is lacking can be determined. Current estimates indicate that the length of potential habitat for this species in the Waikato River network is close to 300 kilometres (excluding habitat above the Hunua dams) and that the proportion of this, where tree planting would be required to create a canopy cover, is about 18 percent (54 kilometres). The proportion of the total habitat that is currently inaccessible to banded kookopu is currently unknown and, as with iinanga, a better appreciation of this will be required in order to map the current habitat that is used as against unused in order to provide a measure of progress with restoration for this species.

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Appendix 7: Fisheries Management

1. Introduction

The roles and responsibilities of central and local authorities regarding the current management of the Waikato River fisheries are encompassed in statutory legislation including: the Fisheries Regulations 1986, Conservation Act 1987, Treaty of Waitangi (Fisheries Claim) Settlement Act 1992, Whitebait Regulations 1994, Fisheries Act 1996, Fisheries (Kaimoana Customary Fishing) Regulations 1998, Fisheries (Amateur Fishing) Regulations 1986, Fisheries (Commercial Fishing) Regulations 2001, Biosecurity Act 1993 and the Freshwater Fish Farming Regulations 1986. Four central and local agencies are involved in the enforcement of these, including the Ministry of Fisheries, Department of Conservation, Fish and Game and Environment Waikato. Some of these responsibilities may change with the implementation of legislation relating to the Waikato-Tainui Waikato River Claim (Speirs et al., 2010).

2. Whitebait

The management of the whitebait fisheries in the Waikato River catchment is an issue of specific concern to the five river iwi (tribe). Particular concerns include:

- Disagreement with council requirements for taangata whenua (locals) to have to license inter-generational whaanau (family) whitebait stands.
- The licensing of new whitebait stands 'over top' [sic] of traditional whaanau fishing sites.
- A lack of monitoring and enforcement (of the fishery itself and associated structures).
- The use of set nets over more labour intensive methods that are considered more 'fair' to the fish.
- Poor maintenance of whitebait stands and, as a result, debris entering the river when these structures break down with no one taking responsibility for their removal.
- That the management and enforcement of activities associated with whitebaiting are covered by separate authorities with neither perceived to be operating in the best interests of the fishery.
- The high number of recreational fishers.

The New Zealand whitebait fishery (including common smelt, and the galaxiids iinanga (whitebait), kooaro (climbing galaxias), banded kookopu (galaxiids), giant kookopu and short jawed kookopu) is managed by the Department of Conservation through the Whitebait Fishing (West Coast) Regulations 1994 and Whitebait Fishing Regulations 1994 prepared under the Conservation Act 1986. These regulations set out the fishing season, limits on the size and type of fishing gear and other criteria. The regulations do vary, with hand-held nets allowed in some areas and fixed nets in others. Outside the West Coast they also allow whitebait to be taken for some customary purposes. People wishing to take the whitebait for hui (meetings) or tangi (funerals) must currently advise a 'warranted officer' of the intention to fish before the whitebait are taken and comply with whatever conditions (e.g., quantity, location, method) imposed by the Department of Conservation. Persons offending against these regulations may be fined up to $5,000.

Because they are structures in the riverbed, the licensing and administration whitebait stands in the lower Waikato River requires a license from Environment Waikato (Waikato Regional Plan, 4.2.6 Whitebait Stands) under the Resource Management Act 1991. Currently there are 427 registered whitebait stands (Speirs et al., 2010). The Department of Conservation retains responsibility for ensuring compliance with the whitebait regulations as they pertain to the use of stands.

Evidence from discussions with tangata whenua during the consultation hui for this Study, Department of Conservation reports and the media shows that conflicts between whitebaiters are increasing. As the number of people fishing continues to increase, conflicts will arise because of a shortage of fishing sites along the riverbanks. This issue requires management of the whitebaiters and does not affect restoration of the fish stocks (see Appendix 6: Whitebait). It is therefore a governance issue requiring better education and management of the whitebaiters' behaviour by the managers of this fishery, the Department of Conservation.

3. Tuna

The five river iwi are also concerned about issues pertaining to the management of the Waikato River tuna fishery. These issues include:

- That commercial fisherman are allowed to take a relatively large amount of tuna compared to recreational and customary fishers and are, therefore, considered to be overfishing this resource.
- That the resource is being exploited for financial gain.
- That there is an inability by iwi to implement traditional sustainable management tools such as raahui (temporary ritual prohibition).

The management of the New Zealand tuna fishery (longfin, shortfin and Australian (spotted) longfin) is currently the responsibility of the Ministry of Fisheries who are bound, under the Fisheries Act 1996, to: *"…provide for the utilisation of fisheries resources while ensuring sustainability"* (see Appendix 5: Tuna). North Island tuna stocks were introduced into the Quota Management System on 1 October 2004. There are four stocks for each of the species in the North Island with the Waikato falling into Area 21 (see Appendix 5: Tuna). Total allowable catches (TAC) in each management area are set under Section 14 of the Fisheries Act 1996 and are regularly updated *"to ensure the best possible outcomes consistent with the purpose of the Act are produced"* (Ministry of Fisheries, 2009). In setting or varying any total allowable commercial catch (TACC) under Section 21 of the Act, the Minister of

Fisheries has to take account of the TAC and allow for Maaori customary non-commercial fishing interests, as well as recreational interests and other mortality caused by fishing (Ministry of Fisheries, 2009). Current allowances for Area 21 are given in Appendix 5: Tuna.

Tuna is a difficult fishery to manage because the relative importance and interaction between habitat, recruitment and fishing pressures have not yet been quantified. There is no control on the life stages of tuna while at sea, so restoration efforts have relied on activities that enhance the population while in freshwater (see Appendix 5: Tuna).

In terms of fisheries management, one of the four approaches suggested to restore the Waikato River tuna fishery in this Study includes:

- Revising the tuna catch regulations to maximise the return per recruit and ensure that sufficient adults reach sexual maturity. (These regulations will need to be applied, not only within the Waikato River catchment, but nationwide through catch limits, raahui and the creation of reserves, if they are to have any positive impact. For shortfins there may also need to be coordination of control with Australian authorities).

To restore tuna within the Waikato River catchment, a tuna management plan with clear and realistic goals needs to be implemented. The plan will need to be adaptive, take account local, regional and national interests and be able to identify information gaps and means to answer them. Tuna population monitoring, surveillance and enforcement will be integral components of the plan. In conjunction with resource owners and managers, it will be essential to develop and implement shortfin and longfin tuna management plans that take into account the aspirations of stakeholders for each of these fisheries (e.g., the Lake Waahi puhi fishery) to restore and maintain a sustainable tuna fishery in the Waikato (see Appendix 5: Tuna).

4. Waikato-Tainui Raupatu Claims (Waikato River) Settlement Act 2010

In the Waikato-Tainui Raupatu Claims (Waikato River) Settlement Act 2010 the Crown acknowledges (a) the importance to Waikato-Tainui of authorised customary activities and the use of traditional whitebait stands and tuna weirs, and (b) the importance to authorised customary activities and use of traditional whitebait stands and tuna weirs as an integral part of the relationship of Waikato-Tainui with the Waikato River. Other provisions state that:

- Authorities must seek and have particular regard to resource consent applications/permits on Waikato-Tainui of authorised customary activities and the use of traditional whitebait stands and tuna weirs, and assess the effects of the activity on the authorised customary activity.
- A member of Waikato-Tainui carrying out an authorised customary activity is not liable to pay, for carrying out the activity, a coastal occupation charge provided for in a regional coastal plan or any other charge.

- Members of Waikato-Tainui may (a) continue to use, maintain and alter their traditional whitebait stands and tuna weirs that were in the Waikato River on 17 December 2009, and (b) replace their traditional whitebait stands and tuna weirs that were in the Waikato River on 17 December 2009 with other traditional whitebait stands and tuna weirs in the Waikato River.
- Joint management agreements between local authorities and the Waikato Raupatu River Trust must include processes relating to customary activities, including:
  - A process for parties to explore (a) whether customary activities could be carried out by Waikato-Tainui without need for statutory authorisation from local authority, and (b) whether customary activities could be provided as permitted activities in relevant Regional or District Plans.
  - A process for the council or the Waikato Raupatu River Trust to carry out (whole or part) the functions of the harbourmaster in relation to the carrying out of authorised customary activities.
  - A process for the development of appropriate protocols between local authorities and the Waikato Raupatu River Trust to the customary practice of placing raahui on part of the Waikato River.

5. Waikato-Tainui Waikato River Fisheries Accord

The Fisheries Accord sets out how Waikato-Tainui and the Ministry of Fisheries will undertake co-management of the fisheries resources of the Waikato River. The Accord also recognises the special relationship that Waikato-Tainui have with all aquatic species found within the Waikato River and provides for the exercise of Mana Whakahaere (authority in respect of the river) by Waikato-Tainui. Waikato Raupatu Lands Trust and Ministry of Fisheries (2009) provides details of the intended implementation of the accord. A joint body will be responsible for prioritising work programmes and allocating resources and funding needed to implement the agreements. It is intended that the agreements will include:

- Co-management projects covering the development of the Waikato River Regulations, fisheries components of the Waikato-Tainui Environmental Plan and the fisheries component of the Integrated River Management Plan.
- Mechanisms to provide for Waikato-Tainui management of fisheries, including the protection of elvers and glass eels, the transfer of fish for enhancement purposes and participation in pest fish eradication.
- Other arrangements that will facilitate the co-management of fisheries resources of the Waikato River.

6. References

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Appendix 8: Fisheries Research

This paper outlines additional research that would be useful in the restoration of the fisheries in the Waikato River. It addresses major information gaps in the biology of several species. This appendix should be read in conjunction with Appendix 5: Tuna and Appendix 6: Whitebait. Those appendices identified the need for research specifically related to restoration actions whereas this appendix deals with more fundamental gaps in our understanding of the river fisheries.

1. Lamprey

Historically piiharau (lamprey) were harvested en route to their spawning grounds in New Zealand rivers, including the Waikato River. Today, piiharau are rare in the Waikato River and most other New Zealand rivers. Reasons for this decline are unknown but not related to overharvest. The construction of dams that block upstream migrations is clearly a factor causing a decline in abundance in this species in some rivers, but not all and, therefore, cannot explain the nationwide decline of this species. Habitat degradation related to changed land use is likely to be a major factor, but until more is known about the freshwater habitats of piiharau, this cannot be proven. Restoration actions to restore the species will only be effective if the factors causing a decline can be clearly identified. Therefore research is required to identify the spawning habitat of lamprey and to determine more about the ecological requirements of the ammocoete larval stage. Identification of spawning grounds would be possible using new tagging technologies but this study would need to be carried out in a small river for logistical reasons. Identification of key factors limiting ammocoete larvae could be carried out in the Waipa River, as the larvae are widespread in this system.

2. Freshwater mussels

Kaakahi/kaaeo (freshwater mussels) still occur in the Waikato River and in the riverine lakes where large stocks once occurred. Restoration of this species (and of kooura (freshwater crayfish)) in the lakes will be dependent on the restoration of water quality and substrate composition in these environments. However, in the river, restoration of kaaeo/kaakahi will require a targeted programme to determine the location of remaining populations coupled with research to identify factors that are limiting or reducing the physical habitat and the recruitment of juveniles to it.

3. Tuna stocking

Restoration of tuna fisheries in the reservoirs involves the trap and transfer of elvers from the base of the Karaapiro Dam into the reservoirs. At present, this operation is working but there is a large loss of elvers related to either their small size (i.e., vulnerability to predation) or to current stocking practice (i.e., the location and abundance) which will severely limit the scope and effectiveness of tuna stocking to restore the fishery. Research is therefore required to determine the relative success of different stocking practices for elvers.

4. Tuna production

Tuna feed heavily on terrestrial foods in flooded marginal land, much of which has been lost through channelisation and flood protection works. However, the value of flood plains for tuna production is unknown. Studies using carbon isotopes are required to determine the proportion of tuna muscle contributed by terrestrial as against aquatic prey to identify the importance of flood plains for tuna production.

5. Pest fish control

Pest fish control is fundamental to the restoration of the fisheries and lakes in the Waikato River. At present, few tools (e.g., netting, rotenone, electric fishing) are available for this. Knowledge of when and where to apply them, and to what species, is lacking. As a consequence, current control is relatively ineffective. Although it is now well established that pest fish in general are impacting on the rivers ecology, there is a lack of knowledge on the causes of the impact and on the life history vulnerabilities of the species. Additional research would provide better evidence-based management, targeting the problem species and specific life stages of the pest fish.

6. Whitebait fishery

A major factor influencing the whitebait fishery in the Waikato River is the West Coast marine environment. Better knowledge of how marine conditions (especially water temperature, food supply and current movements) affect whitebait survival and distribution off the Waikato Coast is required to help inform river-based management. At present, the lack of such information means that the results of river-based management schemes cannot be assessed and may, therefore, be in vain. New approaches such as the extraction of life history and temperature data from otoliths and RNA (ribonucleic acid) typing mean that this is now possible.

7. Lake restoration and fisheries

One of the major information gaps involved in fishery restoration in the lakes, is the change in food webs and how this has affected the native fish species. Fisheries experts in the Study team think that food rather than habitat (or predation) may now be the major limiting resource for native fish (tuna and whitebait). If the main pest fish species that compete with native species for food cannot be eradicated and/or sustainably controlled, then partial recovery of native fish may be possible through the installation of artificial reefs, wave barriers and other in-lake structures. Such structures would need to provide an increase in food that cannot be readily accessed by pest fish. A risk is that they may provide more advantage to juvenile pest fish than to native fish species. Research is therefore required to determine the design and viability of such structures for native species' enhancement. This would be required if lake restoration measures cannot remove or eradicate the pest fish species.