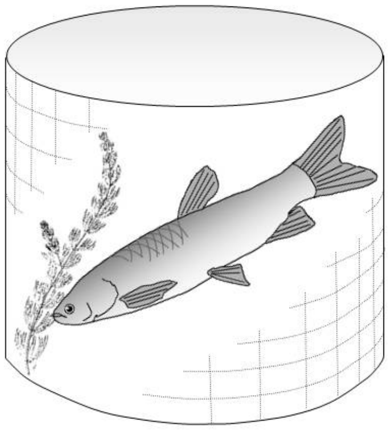
Assessment of the Environmental Effects – the efficacy of caged grass carp (*Ctenopharyngodon idella*) at removing the aquatic weed hornwort (*Ceratophyllum demersum*) in Lake Karapiro

Prepared for MAF

August 2011



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Contents

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1. Executive summary

NIWA have been contracted by MAF to conduct a study to determine the optimal stocking density of grass carp (*Ctenopharyngodon idella*) to eradicate the submerged aquatic weed hornwort (*Ceratophyllum demersum*) within an artificial enclosure.

The purpose of the trial is to contribute to the understanding of grass carp efficacy for aquatic weed control and specifically to develop the science around the potential use of grass carp as an incursion response tool, by determining the stocking density required to remove the aquatic weed hornwort from artificial enclosures within a two month timeframe.

Grass carp are herbivorous fish that were imported into New Zealand with the intent that they would be used to manage aquatic weeds including hydrilla. Grass carp feeding is temperature dependent, and in New Zealand water is at its peak during summer months. This means that stocking densities need to be higher (ca 100 per vegetated hectare) in New Zealand waters than in locations where water temperatures remain high (>20℃) all year round. Grass carp have been shown to eat hornwort (*C. demersum*), and can be successfully contained within enclosures in lakes for the purpose of weed control.

C. demersum (hornwort) is a submerged aquatic weed that has been declared an unwanted organism under the Biosecurity Act 1993. Hornwort is present in many North Island lakes and waterways including the Waikato River, where it is locally controlled. In 2006 hornwort was confirmed as a pest for eradication in the South Island as a MAF National Interest Pest Response.

The proposed study location is at the southern end of Lake Karapiro, near Little Waipa domain. This area of the lake was selected because there are extensive areas of hornwort weed beds of consistent size, density, and water depth to facilitate the placement of cages in comparable sites. Cage design will be based on that successfully used to contain grass carp in Lake Opouahi.

The Waikato River is of particular significance to Maori. The five river iwi Ngāti Tūwharetoa, Raukawa, Te Arawa, Maniapoto and Waikato-Tainui, recognise the river as a tūpuna (ancestor), a taonga (treasure), and for its mauri (life force). Ngāti Korokī Kahukura is the hapū that has dominant mana whenua interest in the rohe around the Waikato River where Lake Karapiro lies.

Lake Karapiro has multiple uses including rowing, sailing, pleasure boating, water skiing, fishing, camping, walking, and picnicking. Water takes for domestic and stock supply are drawn from the lake, and Lake Karapiro provides habitat for native fauna and flora, although native aquatic flora has been largely displaced by hornwort.

For the proposed study, grass carp will be held in the containment structures in the lake for ca 8 weeks over the period of January – April 2012, after which time the cages will be de-constructed and the fish returned to the supplier. The short term nature of the trial coupled with the very low numbers of fish required (compared with the number required to control aquatic pest plants) will not impact on Lake Karapiro. It has been estimated that if all of the fish to be used in the trial escaped or were deliberately released into the Lake Karapiro this would equate to less than one third of a fish per vegetative hectare. No changes in water quality in the lake attributable to the presence of the fish during the trial are anticipated. If grass carp escaped into the lower Waikato River, a self-sustaining population capable of impact will not establish.

2. Introduction

NIWA has been contracted by MAF to assess the efficacy of grass carp (*Ctenopharyngodon idella*) in physical containment to eradicate the aquatic weed hornwort (*Ceratophyllum demersum*). The purpose of the trial is to contribute to the understanding of grass carp efficacy for aquatic weed control and specifically to develop the science around the potential use of grass carp as an incursion response tool, by determining the optimal stocking density required to remove the aquatic weed hornwort from artificial enclosures within a two month timeframe.

Hornwort

Hornwort is an introduced submerged aquatic plant that may occur as stems attached to the sediment, as a floating mat, or drifting fragments. It has whorled leaves that are densely crowded at the apex of the much-branched stems, with 7-12 leaves at each stem whorl. The leaves are 1 to 4 cm long, dichotomously forked, cylindrical and tapered, and conspicuously toothed on one side. The flowers are inconspicuous (2 mm long), solitary, unisexual and auxiliary, with male and female at different nodes. In New Zealand flowers do occur but there is no evidence that viable seed is formed. Propagation is via vegetative reproduction of brittle stem material, (Hofstra and Champion 2006).

Hornwort forms dense monospecific stands up to 7 m tall, and occurs in water depths up to15.5 m. It is characterised by its extremely dense subsurface canopy that displaces and excludes native vegetation through smothering and shading. The displacement of native aquatic vegetation by tall growing submersed alien species is not usual in New Zealand. However, unlike other alien species (e.g., *Egeria densa* and *Lagarosiphon major*) hornwort grows much deeper and also displaces characean meadows to depths that are not impacted by these other alien species.

Hornwort forms rafts of buoyant dislodged fragments, which can be driven into bays or against shorelines by wind where it smothers and shades resident vegetation. This can have concomitant impacts on associated fauna with decline in habitat and water quality. Dense hornwort growth can also impede water flow in irrigation and drainage channels. Buoyant rafts block intake screens, causing problems for the generation of hydroelectricity. Power-generation companies have experienced outages caused by hornwort in New Zealand. Such shut-downs can cost the companies millions of dollars in repairs and lost generation, in addition to costs of constructing booms and screens, and the on-going expense of removing and disposing of weed deposited on the these areas, (Hofstra and Champion 2006).

In the North Island hornwort is present in many regions, with the Waikato River catchment, including Lakes Taupo, Rotoaira and the hydro-lakes being heavily impacted. As part of the National Interest Pest Response, MAF aims to exclude hornwort and eradicate any new incursions from the South Island (http://www.biosecurity.govt.nz/pests/surv-mgmt/mgmt/prog/nipr viewed 8 Aug 2011).

Grass carp

Grass carp (*Ctenopharyngodon idella*, Val.) are herbivorous fish that are native to Asia, deriving their common name, white amur, from the Amur River system that borders China and Russia (Cudmore and Mandrak 2004). The first consignments of grass carp arrived in

New Zealand in 1966 (Chapman and Coffey 1971), and again in 1971 (Edwards and Hine 1974) with initial studies focussed on feeding preferences (Edwards 1973, Edwards 1974). Grass carp were subsequently released for a variety of field studies in small lakes, such as Parkinsons, Waihi Beach reservoir (Mitchell 1980, Rowe and Champion 1993), Elands farm lake (Clayton et al. 1995), Lake Waingata (Rowe et al. 1999) and drainage systems firstly on the Rangitaiki Plain (Edwards and Moore 1975), and then in the Mangawhero Stream (Schipper 1983) and Churchill Drain (Wells et al. 2003), in the Waikato.

Initial studies provided data on the potential use of grass carp for weed control in temperate New Zealand environments and addressed the potential impacts of grass carp in lakes (Rowe & Hill 1989). Issues with respect to containment arose after some fish escaped into the Waikato River (McDowall 1984), and this event resulted in the production of an Environmental Impact Assessment to formally address the use of this fish for weed control in New Zealand (Rowe & Schipper 1985). This report analysed the potential impacts of grass carp, and recorded potential uses, including its potential to eradicate certain problem weed species in lakes. It also confirmed the lack of suitable habitat for grass carp to breed in New Zealand waterways. It was followed by public consultation and an internal report (Rowe et al. 1985) seeking the formal release of these fish for weed control. This was subsequently granted by the New Zealand Government subject to conditions and control by the Department of Conservation and the Ministry of Fisheries.

Since then, grass carp have been deployed in a wide range of locations throughout New Zealand to control excessive weed growth in lakes and ponds. More recently grass carp were used as the primary tool to rid the nation of hydrilla present in Lakes Tutira, Waikopiro and Opouahi Hawkes Bay. In Lake Opouahi, some grass carp were initially retained in a purpose built cage within the lake until the enclosed hydrilla weed bed was consumed. The success of this approach for the hydrilla eradication response, led to the MAF initiative to assess the efficacy of containing grass carp for weed incursion response, which forms the basis of the present study on hornwort.

Location and design

The proposed study location is at the southern end of Lake Karapiro, near little Waipa domain. This area of the lake was selected because there are extensive areas of hornwort weed beds of consistent size, density, and water depth to facilitate the placement of cages in comparable sites. Cage design will be based on that successfully used to contain grass carp in Lake Opouahi (Hofstra and Smith 2009). The cage was assembled on site, and made of netting (10mm wide bird tex, from RJ Reid Ltd) with support posts (steel rod encased in PVC pipe), rammed into the lake sediment. The support posts were linked by a surface rope, to which the netting was attached. The netting extended (ca 80cm) above the water surface, and the bottom edge of the net curtain was weighted and embedded into the lake sediment by SCUBA divers. Depending on the finalised cage sites (within the Lake Karapiro study location) in the summer 2012, the suitability of this cage type may be redesigned. At least six cages will be placed around comparable hornwort beds. These cages (ca 5-6m diameter) will consist of one control (or untreated reference cage) and five treatment cages with different grass carp densities (in a series). Proposed maximum stocking densities are in alignment with that used in Lake Opouahi, and other lakes in New Zealand (ie., approximately 100 fish per vegetated hectare). If sufficient comparable hornwort sites are available, cage numbers will be duplicated. Vegetation (height, cover and density) will be

assessed before, during and after grass carp release by divers (SCUBA). Because grass carp feeding is related to water temperature, temperature loggers (ca 3 depending on the layout and proximity of cages) will be secured to the cages for the duration of the trial. Fouling of the cage walls may occur during the trial and could restrict water flow in the cages. This risk will be mitigated by periodic checks of the net wall (and cleaning if required).
Grass carp (of ca 30 cm in length) will be procured from New Zealand Waterways Restoration, Warkworth. Grass carp health checks, transfer and release are designed to prevent the transfer of any 'hitchhiker species' with the movement of the grass carp, as well as to ensure grass carp welfare. Grass carp will be inspected by NIWA staff on delivery at the lake to ensure fish are in good health. During subsequent monitoring events, observations of fish health/behaviour (if grass carp are seen amongst the weed) will be recorded. The proposed timeframe for the study is two months over summer, however should food supply (hornwort) be exhausted within the cages prior to that time, the study will be concluded (ie., fish removed and returned to the supplier, and cages de-constructed). Conversely, given that the aim of the study is to determine the efficacy of various grass carp stocking densities at removing hornwort, the study will be extended if the highest grass carp density cage (or cages) is close to this goal after two months (ca 80% of the biomass has been removed). The maximum time for extension is dependent on food availability for the fish within their cages, and on an agreed variation to the NIWA/MAF contract. However, given that grass carp feeding activity is temperature dependent, the optimal period for the trial to conclude is before there are significant temperature declines (eg., below 15℃), hence the aim is to undertake the study only for two months, between January and April 2012.

Statutory approvals to introduce grass carp into a waterbody

Statutory approvals (Table 1), and wider stakeholder engagement and consultation for the introduction of grass carp into Lake Karapiro for the proposed containment trial are recognised. As part of this approvals and consultation process, the following assessment of environmental effects has been prepared. This document describes Lake Karapiro, its values, and the potential impacts of studying caged grass carp within the lake, as well as the possibility of grass carp escape or deliberate release during the trial and consequent potential impacts.

Table 1: Statutory approvals required for the release of Grass Carp.

Department of Conservation: The Conservation Act 1987 (Sections 26ZM, 26ZQA) requires Ministerial approval to possess, transfer and release certain kinds of fish, including grass carp. This also requires a grass carp management plan.
Auckland / Waikato Fish and Game Council: The Freshwater Fisheries Regulations 1983 (R59) R59 requires that written consent is obtained from the local Fish and Game Council holding jurisdiction in an area before liberating any fish or fish ova of any description whatever in the waters of any lake, river, or stream within that district.
Ministry of Fisheries: The Freshwater Fisheries Regulations 1983 require that approval is required on first release to a new location. Further releases of grass carp following the initial release are approved on a case-by-case basis by the Ministry of Fisheries. While a second approval should not be required – unless fish are deliberately released from the cages – the Ministry of Fisheries will be kept informed.
Animal Ethics Committee (NIWA): An application will need to be made to the Animal Ethics Committee seeking approval to hold the grass carp in cages for experimental purposes.

3. Values of Lake Karapiro

3.1 Natural Values of Lake Karapiro

3.1.1 The Waikato River and Lake Karapiro

The Waikato River catchment covers 14,260 square km (12 per cent of the area of the North Island). The longest river in New Zealand, it commences its journey to the sea from high in the central plateau, 2797 meters above sea level from where it flows from Lake Taupo. On leaving the lake, the Waikato River passes through the volcanic plateau flowing northward, passing through eight hydro-electric dams before reaching Cambridge, and the Waikato lowlands past Hamilton and to Mercer. Port Waikato marks the end of the river's 425 km from Lake Taupo.

The Karapiro Power Station and dam forming Lake Karapiro (Figure 1 and Appendix 1) was built in 1947. Lake Karapiro, 30 kms south-east of Hamilton, is the last of eight hydro-electric power stations on the Waikato River. The morphometric features of Lake Karapiro are listed in Table 2. All of the Waikato River hydro dams share similar characteristics of high water flow-through and fluctuating water levels. The operating water level of Lake Karapiro fluctuates between 50.5-53.5 m asl.

The lake provides for the recreational activities of many water sports. Rowing regattas are regularly held on what is widely regarded as one of New Zealand's best rowing venues. Events have included the 1950 British Empire Games and the 1978 and 2010 World Rowing Championships.

The New Zealand Herald reported in Thursday Jun 8, 2006

"A FISA inspection panel had visited Lake Karapiro venue in March and said in its report that it was one of the fairest courses in the world they had seen and that the lake was one of the most picturesque in the world." (Federation Internationale des Societes d'Aviron, or the International Rowing Federation).

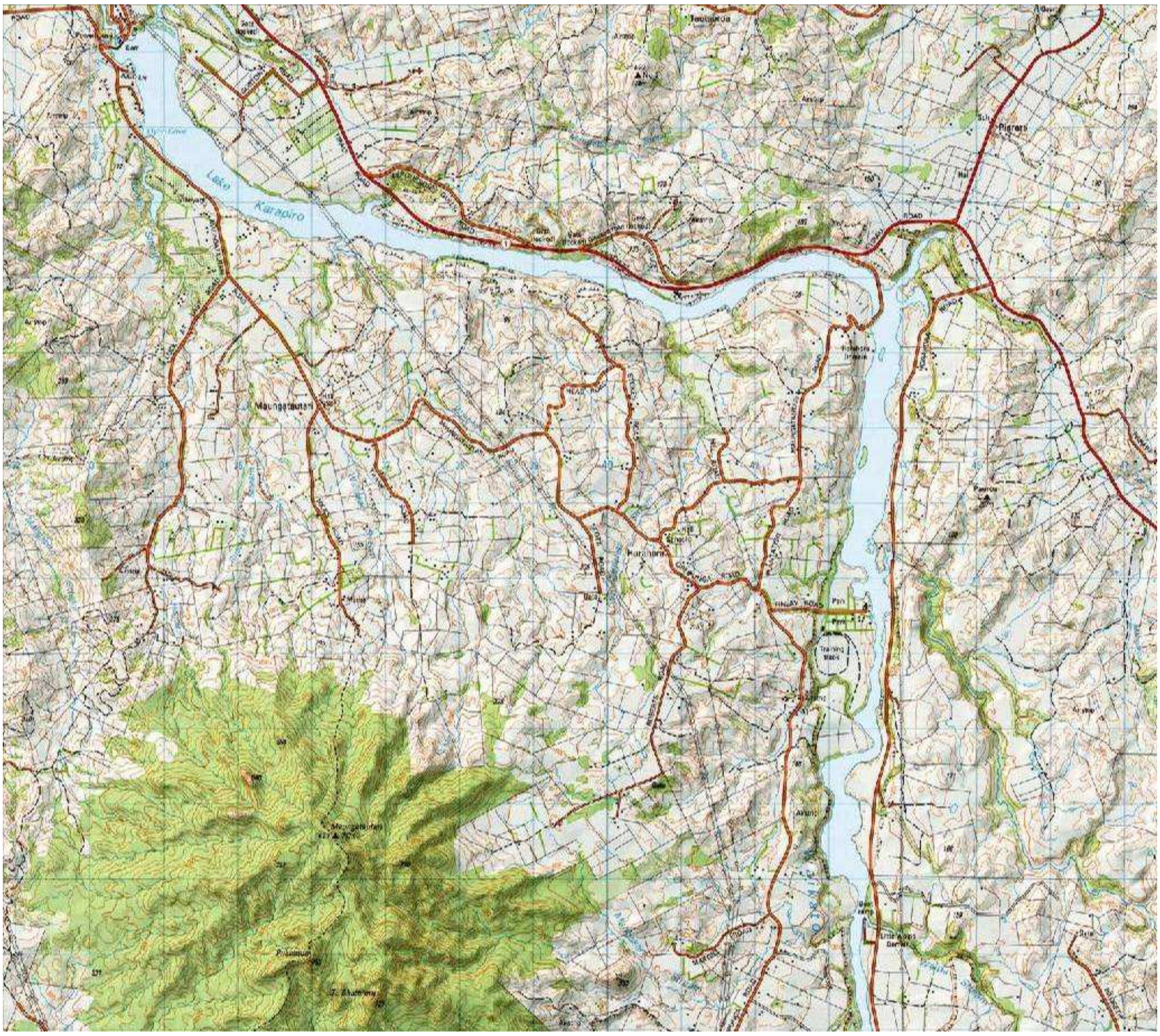


Figure 1: Topographic map of Lake Karapiro (NZMS260 series 1:50,000).

Table 2: Morphometric features of Lake Karapiro.

Co-ordinates	37.92856S 175.544529E
Surface elevation	50.5–53.5m asl
Area (ha)	7.7 ha
Average depth (m)	11 m
Maximum Depth (m)	30.5 m
Maximum Length (km)	11.0 km
Maximum Width (km)	900 m

3.1.2 Water Quality

Waikato River

The water quality of Lake Taupo, source of the Waikato River, is excellent. After leaving Lake Taupo the river flows through the volcanic plateau which quickly changes the character of the water due to the volcanic origins and geothermal fields with increases in sediment, nutrient and mineral loads between Taupo and Lake Ohakuri.

Land use, particularly farm intensification, over recent decades has influenced the levels of nitrogen and phosphorus in the river. Over the last decade increases in both nitrogen and phosphorus levels have been recorded (Waikato Regional Council 2011).

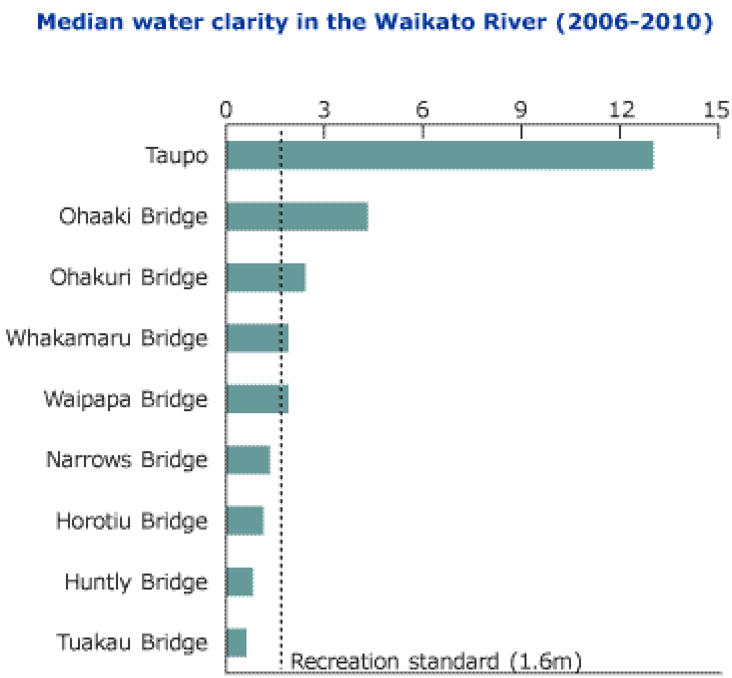
Urban and diary effluent was historically discharged in to the river with little or no treatment. The Waikato River is currently in much better health than it was during the 1950s when the river was considered to be one of New Zealand's most polluted rivers. Urban and diary shed effluent treatment processes have improved considerably since. Biological oxygen demand has improved along the length of the river.

The Waikato Regional Council conducts monthly sampling at 10 sites along the rivers length. While the lower reaches of the Waikato River are nutrient enriched, the river water quality is considered to be excellent when compared with other rivers in the global setting.

Waikato Regional Council data from 2006-2010 indicates that:

> "*water clarity in the river is excellent when it leaves Lake Taupo. ……The river's appearance gradually worsens between Lake Taupo and Hamilton,…*"

The following graph shows the loss of clarity in the Waikato River.



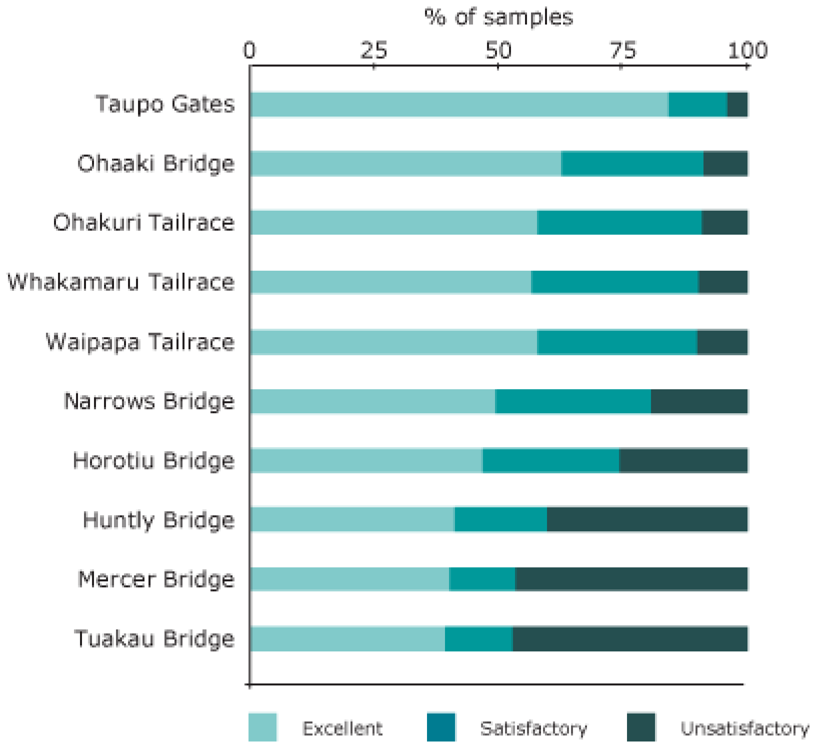
The Waikato Regional Council reports that:

"The hydro dams along the upper river slow down water flow, which in turn affects its quality. Before the dams were built, it took six days for a drop of water to reach the sea from Lake Taupo. Now it takes a month. The increased time that water is held in dams allows the growth of free-floating algal cells (called phytoplankton), especially during the summer. Phytoplankton changes the colour and appearance of the water, making it greener and reducing clarity."

Over the same period (2006-2010) the Waikato Regional Council reports:

"Water quality along most of the Waikato River is good enough for most aquatic plants and animals to be healthy. The graph (below) shows the percentage of water samples at each site that met Waikato Regional Council guidelines for water to support aquatic plants and animals (ecological health)."

Ecological health at Waikato River sites (2006 - 2011)



Lake Karapiro

The Cambridge municipal water supply is drawn from the lake at a point near the Karapiro Dam. This site is within the area previously classified by the Water Resource Council as Class C water. Cyanobacteria are monitored in water drawn from the lake providing the Cambridge drinking-water supply (Hamill 2006).

3.1.3 Aquatic Plants

The submerged vegetation in Lake Karapiro is dominated by *C. demersum*, with other species present including *Egeria densa* and *Glyceria maxima* (also introduced), and the native species *Nitella* aff. *cristata* and *Schoenoplectus tabernaemontani* (Edwards et al. 2010). Early records show that *C. demersum* first appeared in the upper Waikato River soon after completion of the hydro lakes in 1963, from where it spread quickly down through the hydro lakes and dominated the upper reaches of Lake Karapiro by 1972. Today dense weed beds of *C. demersum* dominate the submerged vegetation in seven of the eight Waikato River hydro lakes resulting in some of highest Invasive Impact scores (LakeSPI, in Edwards et al. 2010). In Lake Karapiro a very low native condition is also reported (Edwards et al. 2010).

Invasive weed problems within Lake Karapiro have been in the spotlight in recent years with extensive annual weed control (up to 100 ha) carried out during autumn in preparation for the World Rowing Championships on this lake in 2010.

3.1.4 Fish

Lake Karapiro is home to a range of native and introduced fish species (Table 3), some of which are now landlocked in the lake, while others are stocked annually. The Waikato River Independent Scoping Report (2010) reports:

> *"Prior to the construction of the hydro dams, the Hora hora Falls (near the current Hora hora Bridge, 15 kilometres upstream of Karapiro Dam) would have been a natural barrier to upstream movement by non-climbing fish (e.g., smelt and inanga (whitebait)), whereas the Arapuni Falls (25 kilometres upstream of Karapiro Dam)were the likely barrier to most climbing fish (tuna, lamprey, climbing galaxiids)…….Thus the Karapiro Dam has limited natural upstream fish movement by 15–25 kilometres. However this is mitigated by the elver transfer programme that collects migrating elvers at the Karapiro dam face in December to March each year and transfers them to each of the hydro dams except Ohakuri (avoided due to potential for geothermal-derived metal contamination of tuna)."*
>
> *"Whilst the transfer programme has facilitated the tuna fisheries in impoundments above the lakes, it does not contribute to the spawning runs to the sea because most downstream migrating tuna are killed on passing through the power station turbines"* (Waikato River Independent Scoping Report 2010).

Introduced rainbow trout and shortfin eels dominate the lake fish population with invertebrates and common bullies providing the main food sources for eels, and these prey along with smelt underpinning trout production. No rare fish species occur in Lake Karapiro. The fishery values are confined to the trout fishery, and to eels transferred to the lake as elvers collected at the Karapiro Dam face (Waikato Regional Council 2011).

Table 3: The fish fauna recorded in Lake Karapiro.

Fish species	Shellfish and crustacea
Common bully (*Gobiomorphus cotidianus*)	Freshwater crayfish – koura (*Paranephrops planifrons*)
Common smelt (*Retropinna retropinna*)	Fresh water mussel – kākahi, kāeo, and torewai (*Echyridella menziesi*)
Longfin eel (*Anguilla dieffenbachii*)	
Shortfin eel (*Anguilla australis*)	

Rainbow trout (*Oncorhynchus mykiss*)
Brown trout (*Salmo trutta*)
Catfish (*Ameiurus nebulosus*)
Goldfish (*Carassius auratus*)
Rudd (*Scardinius erythrophthalmus)*
Gambusia (*Gambusia affinis*)

3.1.5 Birdlife

A range of indigenous and exotic bird species dependant on aquatic habitats have been reported on Lake Karapiro (Table 4), with some species such as the Australian bittern and Caspian tern possibly infrequent visitors (Waikato Regional Council 2011).

Table 4: Bird species that have been observed on Lake Karapiro

Australian bittern – Matuku (*Botaucarus poiciloptilus*)
Black Shag – Kawau (*Phalacrocorax carbo novaehollandiae*)
Black Swan, (*Cygnus atratus*)
Caspian tern – Taranui (*Sterna caspi*)
Australian Coot (*Fulica atra*)
Canada goose (*Branta canadensis*)
Grey duck - Parera (*Anas superciliosa superciliosa*)
Grey teal – Tētē (*Anas gracilis*)
Kingfisher – Kotare (*Halcyon sancta vagans*)
Little Black Shag – Kawaupaka (*Phalacrocorax sulcirostris*)
Mallard duck (*Anas platyrhynchos*)
New Zealand Dabchick – Weweia (*Poliocephalus rufopectus*)
New Zealand scaup - Papango (*Aythya novaeseelandiae*)
Paradise shelduck – Putangitangi (*Tadorna variegate*)
Pied stilt – Poaka (*Himantopus himantopus leucocephalus*)
Pukeko (*Porphyrio porphyrio melanotus*)
Shoveler - kuruwhengi (*Anas rhynchotis variegate*)
Spotless crake - Putoto (*Porzana tabuensis plumbea*)
Welcome swallow (*Hirundo neoxena*)
White faced heron - Matuku-moana (*Ardea novaehollandiae*)
Sources: Significant Natural Areas of the Waikato Region - Lake Ecosystems Technical Report (Waikato Regional Council 2011) and www.teara.govt.nz/en/wetland-birds/1 (viewed August 2011).

3.2 Social and cultural values

3.2.1 River iwi and the Waikato

The Waikato River is of particular significance to Maori. The five river iwi Ngāti Tūwharetoa, Raukawa, Te Arawa, Maniapoto and Waikato-Tainui, recognise the river as a tūpuna (ancestor), a taonga (treasure), and for its mauri (life force). The River is tūpuna awa, the ancestral river representing the mana and the mauri of the people. It is central to tribal identity, and to spiritual and physical well-being. For the river iwi it is a living entity, encompassing bed, banks and waters, streams, lakes, catchments and flood plains, flora and fauna, and metaphysical being.

Raukawa and the Crown signed a Deed in Relation to a Co-Management Framework for the Waikato River in December 2009. This became legislation, in November 2010 as part of the Ngati Tuwharetoa, Raukawa, and Te Arawa River Iwi Waikato River Act 2010.

The purpose of the co-management agreements are amongst other matters to:

- promote the restoration and protection of the quality, health and wellbeing of the Waikato River for present and future generations;
- recognise and provide for the kawa, tikanga, mana whakahaere and kaitiakitanga of Raukawa within their rohe.

Raukawa consider that the Waikato Awa holds 'mana' in its own right (spiritual authority and power, or a right to exist in a pristine state for intrinsic reasons) and its life essence or life force is the 'mauri' of the Awa.

Raukawa believe they are kaitiaki of the Waikato River within their own tribal boundaries, subject to the collective and individual rights and responsibilities of their hapū and uri. These rights and responsibilities are hereditary and include the whānau, hapū and iwi responsibility to protect the River.

Raukawa state that "the mauri of the Waikato Awa and the mauri of Raukawa are inextricably linked. As tangata whenua within the region which the River flows, the relationship that exists with the Awa is paramount. It includes the enhancement of our respective tribal mana. However, this also gives rise to the responsibilities to protect the Awa, its mana and mauri. These responsibilities are woven within our customary assertion of mana whakahaere, which is encompassed within long established kawa and tikanga. The purpose of mana whakahaere in this instance is simply 'to ensure the wellbeing of the Waikato Awa".

Raukawa continue to exercise mana, along with customary rights and exert the rights and responsibilities of kaitiakitanga in relation to the Waikato Awa within their rohe. In accordance with the principles of ahi kaa roa; marae, hapu and whanau still reside next to and live every day with the Waikato Awa. The Awa has provided a source of spiritual, cultural, social, and physical sustenance for the people, and in turn the role as kaitiaki embraces respect and an inter-generational responsibility to the Waikato Awa.

Ngāti Korokī Kahukura is the hapū that has dominant mana whenua interest in the rohe around the Waikato River where Lake Karapiro lies, while Raukawa and Ngāti Haua also have associations with the surrounding areas. The two marae Maungatautari and Pōhara are situated on the side of Maungatautari a sacred mountain of the Ngāti Korokī Kahukura and Ngāti Hauā people. The homeland area of Ngāti Korokī Kahukura is described in the Ngāti Korokī Kahukura Trust profile[1] as:

[1] (www.parliament.nz/NR/rdonlyres/E03D4022-7E89-44C7-A7EE-E1BEBB6555BA/132373/49SCMA_EVI_00DBHOH_BILL8792_1_A36019_NgtiKorokKahu.pdf)

"…… from Te Tiki o Te Ihingārangi (an historic pā site on the north western side of Karāpiro) and Te Taurapa o Te Ihingārangi (eastern side of Karāpiro) through Pukekura, Horahora and Maungatautari land blocks to the south eastern corner of the Maungatautari blocks where the Ōwairaka river and our awa tupuna, the Waikato River, meet at Waotu North."

Ngāti Korokī Kahukura Trust describes the special relationship the hapū has with the river:

"We are a river iwi. Our relationship with our awa tupuna (ancestral river) has developed over centuries. It is a unique relationship in that our awa tupuna is the ancestral river of the people, which has its own mauri and spiritual integrity. Our spiritual and cultural well being therefore is inherently linked to the well being of our awa tupuna. The Waikato River is like the blood that streams through our bodies, it is the bloodline of our iwi and there is an urgent need to ensure that our awa tupuna is protected from further degradation. As an iwi who resides by its banks, we have over the generations, developed tikanga and a profound respect for our awa tupuna and all life within it".

"Our tupuna, the late Te Kaapo Tūwhakaaea Clark stated":

"Spiritually the Waikato River is constant, enduring and perpetual. It brings us peace in times of stress, relieves us from illness and pain, cleanses and purifies our bodies and souls from the many problems that surround us…"

"Te Kaapo is poignantly quoted regarding the price paid by Ngāti Korokī Kahukura in the Waikato River Report, a confidential working document prepared to assist the Waikato River negotiating team under the leadership of Dr Ann Parsonson, Historian;

"Unmentioned in the official account of the building of Karapiro is an effect of the rising lake waters that caused particular distress to Ngaati Korokii-Kahukura of Maungatautari. Their burials were all along the banks of the Waikato River. As the dam at Karapiro was completed and the River flooded in 1947, the kaumatua tried to ensure the safety of their wheua (bones), but the authorities did not listen.

"Our kaumatua Taupua Winikerei was one of those who tried to bypass the Public Works to look after our waahi tapu along the River. Nobody would listen to them, they were just there to do their jobs. The people had no mana, no strength to pursue this take. When they flooded the River many wheua rose with the water. They had come out of the caves along the River gorge. Our people had to go onto the lakes and collect these bones. The same thing happened with the other waahi tapu. Instead of listening to our kaumatua they just moved part of it and flooded the rest. That was a hard time for our old people. The two rapids, Aniwaniwa and Karapiro, and the rock has since been inundated by water of the Karapiro Hydro-Electric Dam. The damming of the river meant loss of land though flooding. Landmarks, the eel holes, and other food sources were also lost".

Kuia, Iti Rawiri of Te Awamaarahi Marae, Te Kōhanga (near the mouth of the river) sums up the esteem that the river tribes hold and the values they place on the Waikato River (http://www.cruise-waikato.co.nz/waikato_river_history_3.html):

"The Waikato River is a tūpuna and looks after us throughout our lives. The River feeds us, nurtures us, and takes care of us, healing our hurts and protecting us from harm. The River's spiritual powers are as important today as they were in the past".

"The power of the River does not change or dwindle with the passing of the year; If people were going on a journey, they would go to the River first before leaving the area".

"This is still practiced today. When people were sick, we would send them to the River to anoint themselves and be healed. This is still practiced today. To us, the most important thing about the River is the waters healing power".

"Tikanga relating to the River cannot be separated from Kīngitanga and Pai Mārire, the faith that sustains it. Spiritual and legal protections are embodied in Kīngitanga and Pai Mārire which celebrate all that God has created, uniting families and Kīngitanga communities."

Waikato-Tainui have a duty to past, present and future generations to protect the river. This duty was recognised in the deed of settlement signed between the Crown and Waikato-Tainui. The Waikato-Tainui Raupatu Claims (Waikato River) Settlement Act 2010 acknowledged the Waikato-Tainui interest in the river paving the way for co-management to be established.

The Ministry for the Environment commissioned NIWA to prepare an independent scoping study "Waikato River Independent Scoping Study" for the incoming Guardians of the Waikato River Guardians Establishment Committee (a precursor of the Waikato River Authority) (www.mfe.govt.nz/publications/treaty/waikato-river-scoping-study/index.html). The Waikato River Authority, is a partnership of the Crown with the five river iwi, vested with the responsibility of realising the vision for a healthy and better managed Waikato River. The report, released in December 2010 by the Waikato River Authority at its first meeting, provides an assessment of the health of the Waikato River and its catchment recommending actions that could be undertaken to restore the river.

3.2.2 Recreation and water use

The Karapiro Dam was commissioned in 1946. The formation of the lake led the Waipa District Council to establish a domain adjacent to the lake. The 19 hectare recreational reserve, now named the 'Mighty River Domain', is open for public access all year round. Lake Karapiro now has multiple uses including rowing, sailing, canoeing, pleasure boating, water skiing, fishing (eels and trout), camping, walking, and picnicking. Water takes are drawn from the lake for domestic and stock supply.

The Waikato Regional Council has advised that the proposed activity i.e. the construction of the temporary cages to hold the fish is permitted under the WRP Rule 4.2.17.1. A resource consent is not required.

The use of water craft and navigation in Lake Karapiro falls under the jurisdiction of the Waikato Harbour Master. The Harbour master is comfortable with the proposal.

Lake Karapiro is a regionally significant trout (brown and rainbow) fishery, providing opportunities for both boat and shore based fishing. The lake is stocked annually with both rainbow trout and eel species. Fish and Game reports that:

> *"Growth rates for the trout yearlings (12cm) released into Lakes Arapuni and Karapiro in May last year have been outstanding with most of these fish reaching 40+cm by mid-January. ……..The reason for the rapid growth is the vast schools of smelt present in both lakes, probably the best conditions for growth and fishing for some years."*
> www.fishandgame.org.nz/Site/Regions/Auckland/fishingNews/February2011.aspx

3.3 Summary of lake values

Following the completion of the hydro-electric dams, the aquatic weed hornwort was first confirmed as being present in 1963. By 1972 when hornwort was confirmed in the upper reaches of Lake Karapiro it was present in all of the Waikato River hydro-electric dams. Today, hornwort dominates the aquatic flora in Lake Karapiro, and native flora values are low. No rare or endangered fish species are known to be present in Lake Karapiro. The lake is stocked with elvers retrieved from the base of the Karapiro dam. Lake Karapiro is a valued trout fishery that is stocked annually with rainbow trout fingerlings. A wide spectrum of bird species are known to frequent the lake. Casual visits by rare or endangered bird species occur.

Aside from water storage and water takes, Lake Karapiro is used for many recreational activities including, rowing, sailing, canoeing, pleasure boating, water skiing, fishing (eels and trout), camping, walking, and picnicking.

The Waikato River and its surrounds have a long history of use by the river tribes. The river and its surrounds are a living entity representing the mana and the mauri of the people central to tribal identity, spiritual and physical well-being.

4. Grass carp effectiveness for aquatic weed eradication

Grass carp are herbivorous fish, which were imported into New Zealand with the intent that they would be used to manage aquatic weeds (Rowe and Schipper 1985). They have been used successfully overseas for the control of hydrilla (*Hydrilla verticillata*), and in New Zealand for the eradication of other submerged aquatic macrophytes (Rowe and Hill 1989). In New Zealand grass carp have successfully eliminated *Egeria densa* from Lake Parkinson, *Elodea canadensis* from Lake Waingata and hydrilla from Lake Eland (i.e., no plants have been found since 2003, known tuber viability indicates that eradication cannot be declared until 10 years after the last plant). They have also eliminated submersed weed species from a large number of ponds and private dams.

Grass carp are warm-water fish (Rowe & Schipper 1985) and feeding on macrophytes begins at temperatures over ca. 15ºC, when the young fish reach a length of ca. 150 mm and feeding activity increases with both fish size and water temperature up to at least 30ºC. Grass carp feeding in New Zealand waters is therefore maximal during summer months and minimal during winter with the feeding season being largely determined by water temperatures. This means that stocking densities need to be higher in New Zealand waters than in locations where water temperatures remain high (>20ºC) all year round. It is clear from the use of this fish both overseas and in New Zealand to date, that grass carp will eat most aquatic plants (native and introduced species) and, at the right stocking density, have the capacity to eradicate the introduced 'oxygen-weed' species (Hofstra 2011).

4.1 Case study - Lake Eland

Lake Eland (Hawke's Bay) is a 4 ha spring fed shallow dam (max depth 7 m) lake on a privately owned farm (Champion unpublished data 1988). In the 1980s when it was first reported, hydrilla covered ca 1 ha of the lake growing down to ca 4.5 m depth. Following confirmation that hydrilla had established in Lake Eland, a trial commenced in 1988 to determine the effectiveness of grass carp to control, and potentially to eradicate, hydrilla (Neale 1988). As it has no inlet or outlet streams and is isolated from public access, Lake Eland was ideal for the grass carp trial.

The trial design included an assessment of water quality, invertebrates, vegetation, fish and birds (Neale 1988). Water quality and invertebrates were monitored by the Hawkes Bay Catchment Board. Triploid grass carp were supplied by Ministry of Agriculture and Fisheries, birds counts were undertaken by the Department of Conservation, and vegetation was monitored by the Aquatic Plants Section MAF Tech (now NIWA) (Neale 1988).

An aquatic plant survey in 1987 included five emergent species (*Typha orientalis, Schoenoplectus tabernaemontani, Juncus edgariae, Bolboschoenus fluviatilis, Eleocharis acuta*), four marginal species (*Persicaria decipiens, Ludwigia palustris, Lobelia perpusilla, Callitriche stagnalis*) and twelve submerged species (*Glossostigma elatinoides, Glossostigma submersum, Lilaeopsis ruthiana, Elatine gratioloides, Potamogeton crispus, Potamogeton cheesemanii, Potamogeton ochreatus, Chara corallina, Nitella cristata, Myriophyllum propinquum, Elodea canadensis* and hydrilla) (Clayton et al. 1995). Amongst the submerged species all but hydrilla occurred in less than ca 1 m of water, 5 species had less than 5% cover, the *Glossostigma* species and elodea had 76-95% cover and the hydrilla had 100% cover to 4 m and occurred to depths of 4.5m (Neale unpublished report ca 1988). Hence the native plants that were present in the lake had a limited distribution and abundance with hydrilla dominating the littoral zone of the lake bed (Neale unpublished report ca 1988).

Triploid grass carp were stocked by MAF Fish in December 1988. Initially 100 fish/ha of ca 270 mm in length were stocked in November 1988 (Clayton et al. 1995). An assessment of vegetation in April 1990 revealed a major reduction in hydrilla, 17 months after grass carp were released. At this time the native plants *Glossostigma* and *Typha* were not visibly reduced, however in April 1991 evidence of grass carp browsing on *Typha* was first noted, whilst the dense beds of *Glossostigma* and *Lilaeopsis* remained to a depth of ca 2 m and were abundant to 1 m (Clayton et al. 1995). In November 1991 extensive searches at depths of 1-1.5 m revealed occasional hydrilla plants re-growing from tubers or buried stems, predominately in areas supporting low growing turf plants and amongst fallen tree branches (Clayton et al. 1995). Sediment sampling down to 3 m water depth also revealed viable tubers. However no plants or re-growth occurred in areas of the lake deeper than 1.5 m down to 4.5 m, the predominant depth range of hydrilla before grass carp (Clayton et al. 1995). An annual (April) vegetation survey of Lake Eland has continued since then, with a single hydrilla plant last found in 2003, and more recent surveys reporting only the continued presence of the turf plant community (Hofstra et al. 2008), and young raupo (Hofstra et al. 2004).

As a landlocked lake, Eland had no fish of any intrinsic value in the absence of migration pathways to the sea (eg., no self-sustaining eel population). However, trout had previously been stocked along with common bullies as a food source for the trout. Common bullies were present in low numbers at the time of the grass carp introduction (Neale unpublished report ca 1988), and more recently were recorded as being abundant (Hofstra et al. 2008). Bird surveys conducted over the years have indicated that the species present now are comparable with those present pre-grass carp and hydrilla eradication (Champion, unpublished survey sheet dated April 1989). The number of invertebrate taxa found in the lake has remained similar, however there has been a shift in diversity - i.e., snails were not found in the 2008 survey, but mites were (Hofstra et al. 2008).

Although stocked with trout at one time, the lake was considered more suitable for wildfowl than recreational or fishery purposes, receiving high nutrient loads from its ca 26 ha pastoral catchment (Sander 1994). Lake Eland is eutrophic, as indicated by summer mean chlorophyll values (chl-a) and phosphorus concentration and is subject to algae blooms. A thermocline forms occasionally at ca 2m depth, with bottom waters becoming anoxic in the late summer. Water quality results indicate little change as a consequence of the introduction of grass carp to Lake Eland. However, determination of water quality changes over time is difficult based on the data available as sampling was irregular (Sander 1994).

The Lake Eland grass carp trial has demonstrated the effectiveness of grass carp at removing hydrilla, while a turf plant community is retained and so too is the habitat for a range of macroinvertebrate taxa, common bullies and waterfowl.

4.2 Case study – Contained grass carp in Lake Opouahi

Lake Opouahi is the smallest (ca. 6ha) and highest (480 m a.s.l.) of the currently hydrilla affected lakes and is located in the hills north and inland of Lake Tutira. It is situated in the Department of Conservation administered Opouahi Scenic Reserve, which has, under a joint venture arrangement with ECOED (Environment, Conservation and Outdoor Education Trust) also become home to the Opouahi Pan Pac Kiwi Crèche following the construction of predator proof fencing by ECOED.

Lake Opouahi has high scenic values and is surrounded by native bush and swampland with ca. 20 to 30% of the lake's catchment (44 ha) in farm land (Hooper 1987). There are several small inlet streams that pass through the northern wetland and the main inflow to the lake from the swamp is the Waipapa Stream. The lake outflow on its southern side is the Awatamatea Stream which eventually joins the Waikoau River (Hooper 1987). Hydrilla was first noted in Lake Opouahi in 1984 (Walls 1994), and is likely to have established at some time between 1970 and its first record, because it was not reported in a lake vegetation survey in 1970 (Department of Lands and Survey 1981). At the outset of the MAF hydrilla eradication response hydrilla formed discrete clumps of vegetation within the lake littoral zone, as well as a dense weed bed near the jetty (Hofstra et al. 2008).

The lake and its surrounds are visited for hiking, bird watching and picnicking, and the lake itself provides water for adjoining properties. Water takes from the lake were problematic for the proposed use of herbicide to reduce hydrilla near the jetty. As a result, an alternative solution was devised. A containment fence was constructed around the hydrilla at the jetty and a number of the grass carp scheduled for release into the wider lake for hydrilla control, were released inside the fence. The intention was to retain the fish within the fence for four months, by which time it was anticipated that the hydrilla would be reduced to an acceptable level. However, the grass carp acted more quickly than expected and were released into the rest of the lake in two months, as all vegetation within the contained area had been consumed. This result highlighted the potential for grass carp to be used for aquatic weed control and/or eradication through a contained or 'mob-stocking technique'.

5. Potential environmental effects of grass carp

The potential impacts of grass carp in New Zealand waters were addressed by Rowe & Schipper (1985). Predation on other fish is not an issue as grass carp have no teeth and once over about 150 mm in length are herbivorous. Furthermore, as they only breed in rivers that meet stringent conditions on flow, river length, juvenile rearing habitat, and water temperature, they will not breed in New Zealand waters. Stocked populations will eventually die out unless restocking is undertaken to replenish populations. Their life span in the wild is likely to range from 10-20 years.

Research in both New Zealand and overseas during the past twenty years has shown that the main impacts arising from the use of the grass carp in lakes is related to their removal of all aquatic and marginal vegetation and the consequences of this on the lake ecosystem (Rowe 1984; Mitchell 1980; Mitchell et al. 1988; Rowe & Schipper 1985; Rowe & Hill 1989; Rowe et al. 1999). As the amount of aquatic vegetation varies greatly between lakes, any impacts need to be considered on a case-by-case basis.

Where fish are released in sufficient numbers to control aquatic pest plants in a body of water, small shallow lakes where vegetation is a major component of the ecosystem will be more affected than large deep lakes where the vegetation is a relatively minor component. Stocking densities would need to approximate 100 fish per vegetative hectare to achieve biological control.

Lake Karapiro

Lake Karapiro occupies some 770ha, within which the weed hornwort is able to grow down to ca 5m water depth. Approximately 210ha of the lake area are less than 5m in water depth and so the potential area that could be occupied by weed growth is about 27%.

At the recommended stocking rate of 100 grass carp per vegetated hectare that area of weed would equate to ca 21,000 grass carp to achieve effective weed control in Lake Karapiro. This is not contemplated, but the number of grass carp required to have an impact on the current weed biomass of this lake is clearly very large and well in excess of the number required for this trial.

In the proposed study there will be a total of about 60 fish in cages, for a period of two months after which the grass carp will be removed from the lake. During the study it is expected that hornwort within the cages will be reduced or eliminated. Once the fish and cages are removed the weed will return.

However, in the event that the fish were accidentally or deliberately released, the grass carp will be contained (by the hydro-dams) and the resulting stocking density within the lake will be less than a third of a fish per vegetated hectare, well below the level required to achieve weed control. No effect would be perceptible.

In the unlikely event that the grass carp remained in a school, and resulted in localised higher stocking density, hornwort may be reduced locally, and could even result in temporarily improved habitat for low growing native plant species that grass carp are unable to graze on account of their low stature of the plants.

5.1 Summary of effects

The river iwi identify with the Waikato River. The introduction of grass carp into Karapiro albeit temporarily may be viewed as introducing another alien species despite its presence in the lower reaches of the river.

The environmental effects of introducing grass carp into Lake Karapiro for the period proposed will be imperceptible. Outside of the cages in which the fish are contained any effects will be too small to be measured.

In the event that the fish escaped or were deliberately released their presence in the lake until they die would similarly be both undetectable and imperceptible. Escapement to the lower Waikato River would also have no measurable effect. Rowe & Schipper (1985) acknowledged that spawning of grass carp could occur in this river, but concluded that the buoyant eggs would either be washed out to sea before they could hatch, or survival would be too low to result in a reproducing population. Grass carp spawning requirements differ from those of the other carp species (i.e., koi carp, common carp, silver carp, blackhead carp) that have caused significant problems in rivers in other countries.

The successful elimination of hornwort by grass carp and the identification of suitable stocking rates to eliminate hornwort within an eight week window will provide a valuable platform from which this potential tool for future aquatic pest plant biosecurity responses can be developed.

6. Mitigation Measures

Appropriate mitigation measures for the management of the confined grass carp during the course of the trial are set out below.

River iwi

NIWA has advised Waikato-Taimui, Ngāti Korokī Kahukura and Raukawa of the trial. NIWA will maintain communication regarding the trial with Ngāti Korokī Kahukura and Raukawa throughout the duration of the trial.

Risk of release

Evidence based on historical attempts to contain grass carp within targeted sites suggests that future escapes are inevitable, either on account of unpredictable climatic events resulting in failure or damage to control structures, or from human error or intervention. This is particularly true for open or interconnected water systems that require construction of screens or fish barriers to confine the fish, rather than for land-locked waterbodies that have, understandably, never presented a significant risk of escape.

The most significant and well known escape was of 1500 - 2500 diploid grass carp into the Waikato River from the AkaAka drains in 1984. This was due to the failure of a screen, (designed and installed by Council engineers to prevent escapement,) to withstand the erosion forces of a large flood event. The main effect of any escapement would be to compromise the trial rather than the environment.

The water levels of Lake Karapiro fluctuate due to hydro-electric operational requirements and flooding. Following discussion with Mighty River staff it was recognised that likely lake level changes at the study location could be mitigated by the cage design, and so minimise the risk of accidental escape during the trial. The research team will be in contact with MRP staff in the period during cage construction and throughout the trial.

Critical points at which fish might be accidentally released occur during transfer to and the recovery from the cages. Fish will be sedated for transfer from the fish farm to Karapiro. Experience with the system put in place for transferring fish to and the stocking of the Tutira lakes will be applied in this project. The likelihood of escape during this phase has been assessed as being very low. Staff from New Zealand Waterways Restoration Ltd (NZWR) will be involved in recovering the fish from the cages.

It is possible that grass carp may be deliberately (or accidentally) released from cages following interference by member of the public. This will be mitigated by minimising access to cages, for example, keeping the cages well within weed beds reduces the likelihood that anyone would deliberately or accidentally take a boat into them. If released, fish will be confined to the stretch of river bounded by the Karapiro (downstream) and the Arapuni (upstream) dams. Fish attempting to move downstream as they might and surviving the turbines (an unlikely event) in the Karapiro power station would find themselves in a catchment where grass carp are already present. Rowe and Schipper (1985) have reported that there have been no impacts of grass carp in riverine environments because densities remain too low to affect macrophytes.

In the event that grass carp did escape no mitigation measures are envisaged for changes in water user activities as no negative effects on lake flora, fauna, or health are expected.

7. Grass Carp Operation

The goal of the trial is to determine the effective stocking rate to allow hornwort elimination in an eight week period. Grass carp will be contained (mob stocked) for the period of the trial in up to 12 cages each measuring ca 6m x 6m. The effective use of contained grass carp for weed removal has been demonstrated in Lake Opouahi.

Siting the cages

The cages will be located, if possible, in one continuous weed bed in the proximity of Little Waipa at the southern end of Lake Karapiro.

Siting of the cages will be determined by considerations including: bottom bathymetry, oxygen exchange, adjoining weed density, water through flow, access and visibility.

Containment

Deliberate or accidental release of grass carp from the cages will be managed within the resources available. While grass carp are generally very wary and intelligent fish, and are particularly difficult to catch, any attempt to catch or unduly disturb them while in the cages could lead to the fish attempting to escape. Observed escape behaviours have been to either attempt to find a passage under, or to jump over the top of the net. Any deliberate removal through capture is not likely to be successful. Changes in grass carp numbers present in any of the cages, due to escape, release or capture, will reduce browsing pressure on the hornwort and compromise the trial outcomes.

Cage structures

The containment structures will be built to minimise the likelihood of escape. The walls and top of the cages will be constructed using horticultural bird netting. The top of the cage will be supported by a buoy mechanism to allow fish access to the air in the unlikely event that the water within the cages becomes oxygen deficient.

Fluctuating lake levels

One of the influencing factors when selecting Lake Karapiro was the size and location of the hornwort beds, and the ability within that location to design cages that could move (rise and lower) with the likely water level fluctuations. Mighty River Power has been consulted and contact will be maintained with key personnel throughout the course of the trial to anticipate fluctuations in water level. The containment structures will be designed to accommodate fluctuations of ca 1.5 meters. Annual lake level lowering for weekend maintenance only occurs in August and these lower than normal levels will not be experienced during this grass carp trial.

Stocking of grass carp

Grass carp of a minimum length of ca. 300 mm will be stocked into the cages at varying densities. This minimum size is required to avoid predation by shags and to ensure herbivory. The fish will be supplied by the contracted supplier.

Monitoring of the trials

Visits to the trial to monitor progress are planned at 2, 4 and 6 weeks following release of the fish into the containment structures.

Contingency plans for escape

Should grass carp escape or be deliberately released from the cages, they will be confined by the Karapiro and Arapuni Dams. These fish are too few in number to have any noticeable impact in the lake flora and they will not reproduce in the Waikato River (Rowe & Schipper 1986).

The main contingency plans following an escape of grass carp will revolve around re-stocking the cages if possible (and in agreement with MAF) to maintain browsing pressure on the hornwort. This will require prior identification of the cause(s) of any breach and the subsequent repair (if necessary) of the cages before restocking. It may also involve further management of other factors responsible for or contributing to the escapement. Once security is re-established and unlikely to be breached again, restocking could be undertaken.

Proposed schedule for management actions

A tentative schedule identifying the sequence and timing of key actions for the trial is outlined in Table 5.

In order to both stock grass carp during the summer growing season and allow sufficient time for them to browse down the hornwort, a decision for the requisite approvals will need to be obtained by 30 November 2011. This will allow for the building of the cages and other management actions to be undertaken before stocking occurs. The intended time for stocking is late January / early February 2012 otherwise the trial would need to be delayed until the following summer.

Table 5: Proposed schedule of actions for the contained grass carp trial in Lake Karapiro.

Management action	Time/periodicity
Preliminaries:	
1. Preparation of AEE	July 2011
2. Inform key stakeholders and make AEE available	August 2011
3. Seek approvals from the Minister and Director General of Conservation	Aug – Oct 2011
4. Confirm cage design	Nov 2011
Assuming the application is approved:	
1. NIWA confirms location of trial site(s)	TBA
2. NIWA confirm delivery date for grass carp	16 Jan 2012
3. NIWA constructs containment cages – on site modifications made if needed	TBA
4. Stock grass carp	TBA
On-going management:	
1. Trial monitored	TBA
2. Fish removed	TBA
3. Cages dismantled	April 2012
Final report:	
1. Report tabled with MAF	27 June 2012

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Appendix 1. Lake Karapiro bathymetric map (Irwin 1978)