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.

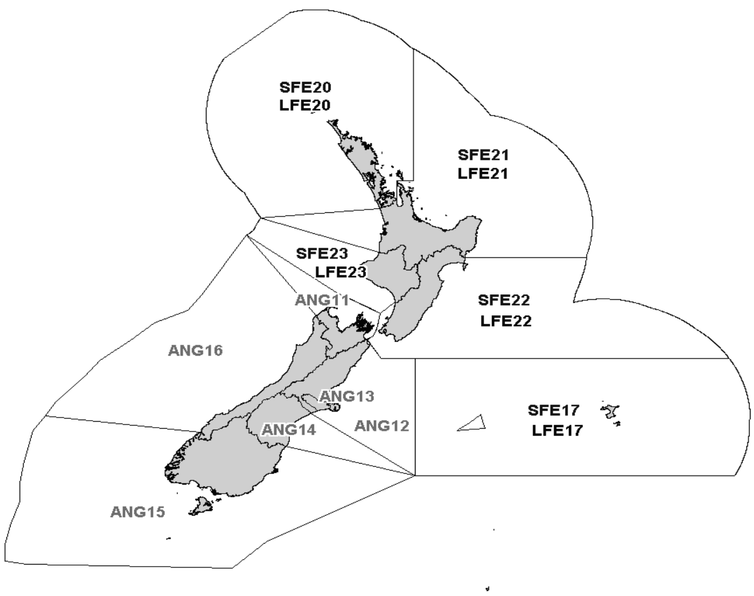

Figure 1: Quota management areas for shortfin (SFE) and longfin (LFE) tuna stocks in New Zealand as from 1 October 2004 (from Ministry of Fisheries, 2009)

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.

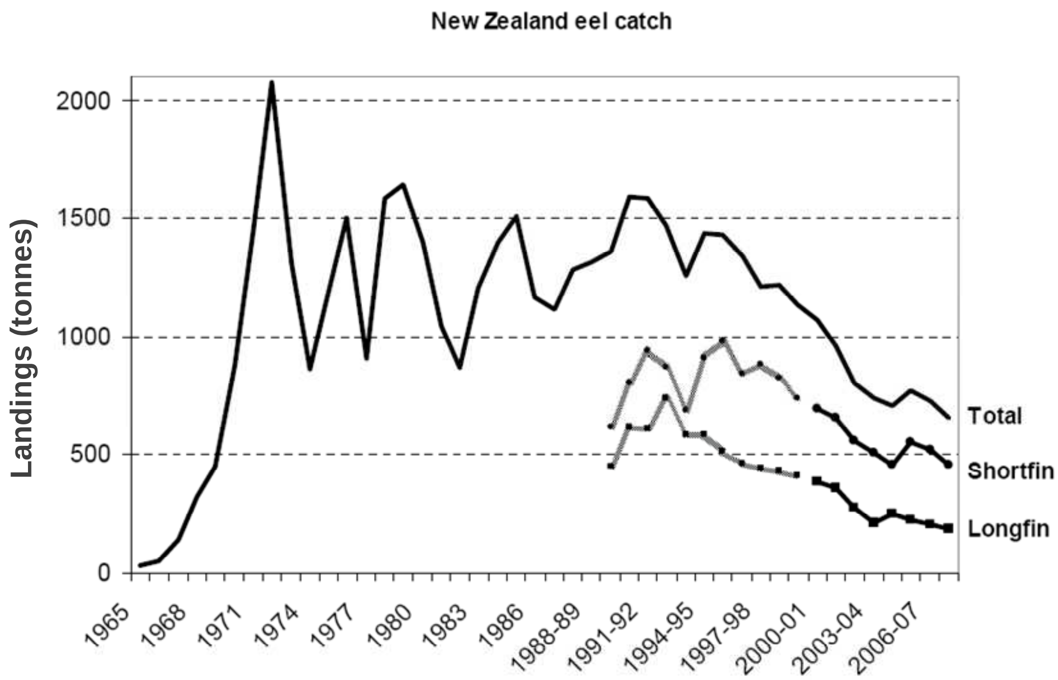

Figure 2: Total New Zealand tuna landings from 1965–2007/08. Estimated shortfin and longfin landings from 1989–90 to 2007–08 are also shown. The grey lines are for the period prior to the introduction of 'Tuna Catch Landing Return' forms providing data on catches and were generated by pro-rating the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

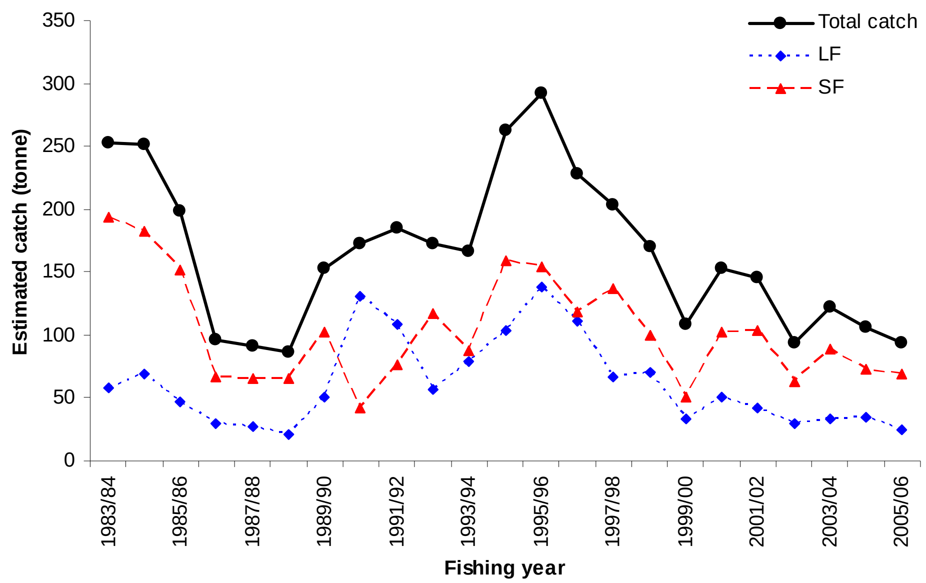

Figure 3: Total estimated catch of tuna, and the proportion of longfin (LF) and shortfin (SF) tuna in the commercial catch for the Waikato Basin (Statistical Area AD). Data for 1983–84 to 1989–90 from Jellyman (1993); data for 1990–91 to 1998–99 from Beentjes and Bull (2002). Official records after 2005–06 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].

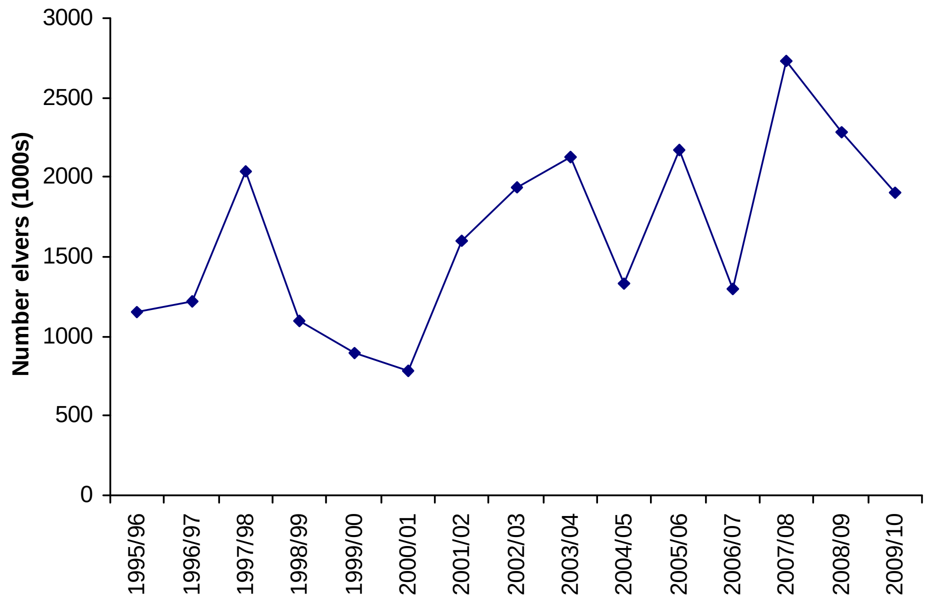

Figure 4: Total number of elvers captured at Karaapiro Dam 1995–96 to present. Note: although the trap and transfer programme began in 1993–94, comparable information is only available since 1995–96 (e.g., when the current trapping system was installed).

[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.

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[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

<u>Action C1</u>

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.

<u>Action C2</u>

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.

[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

[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)

Action H

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.

Action I

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.

Action K

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

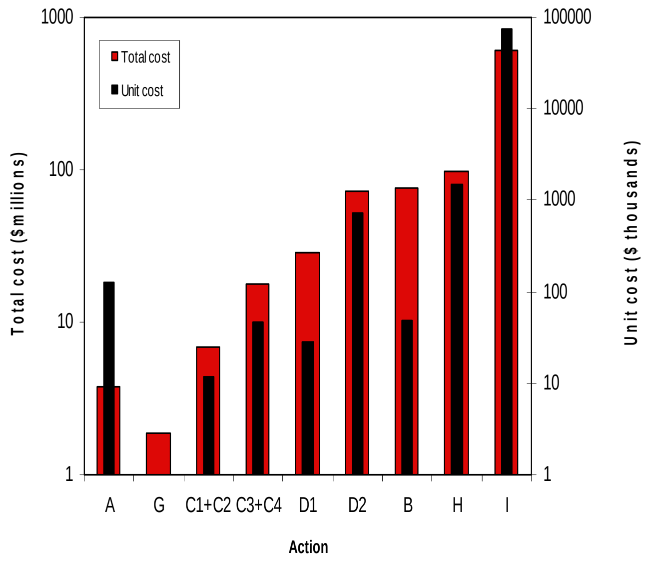
Table 4 shows the least to the most expensive action in terms of total discounted capital and operational costs for tuna restoration. Capital costs are assumed to occur in the first year (2011), whereas operational costs are occurring on an annual basis until 2040, unless specified differently. Capital 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).



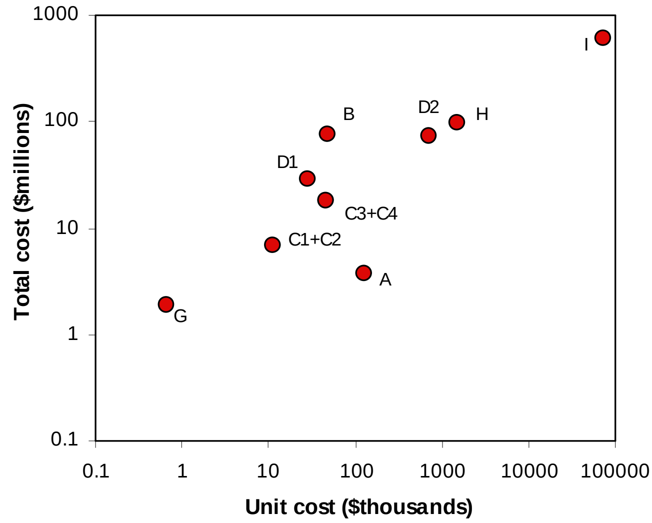


Figure 5: Comparison of total and unit costs of all actions (discounted at eight percent).

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

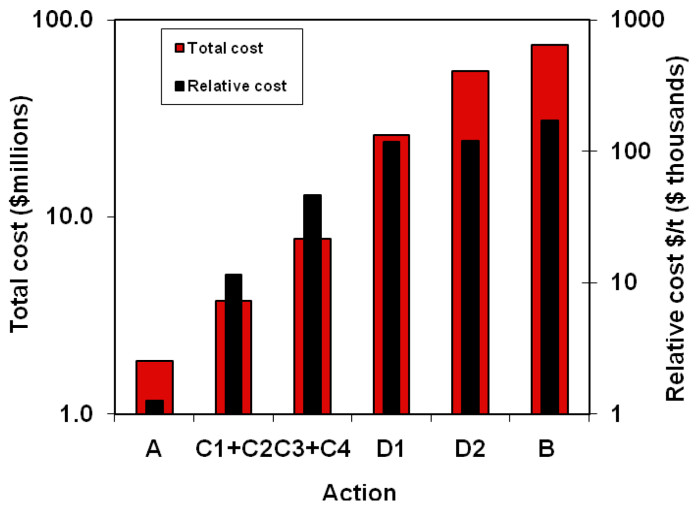


Figure 6: Total and relative cost of actions per tonne of tuna restored.

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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