Appendix 6: Whitebait

1. Introduction

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

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

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

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

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

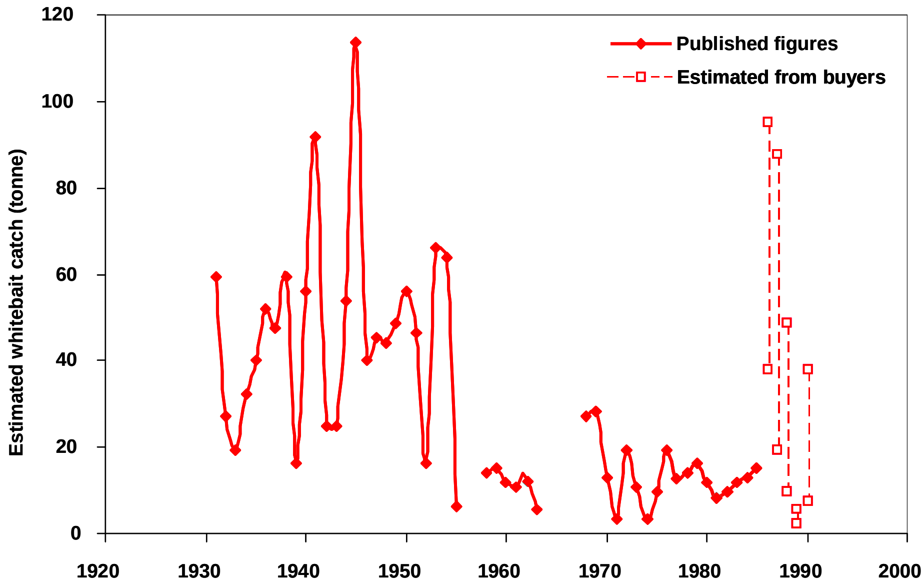

Figure 1: Estimated annual total catch of whitebait from the Waikato River (galaxiids (kookopu) plus smelt) based on catch records from Marine Department records (1931–1973), an Auckland canning factory (1958–1963) and commercial buyers' records (1975–1990). Figure from Baker and James (2010).

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

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

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

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

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

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

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

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

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

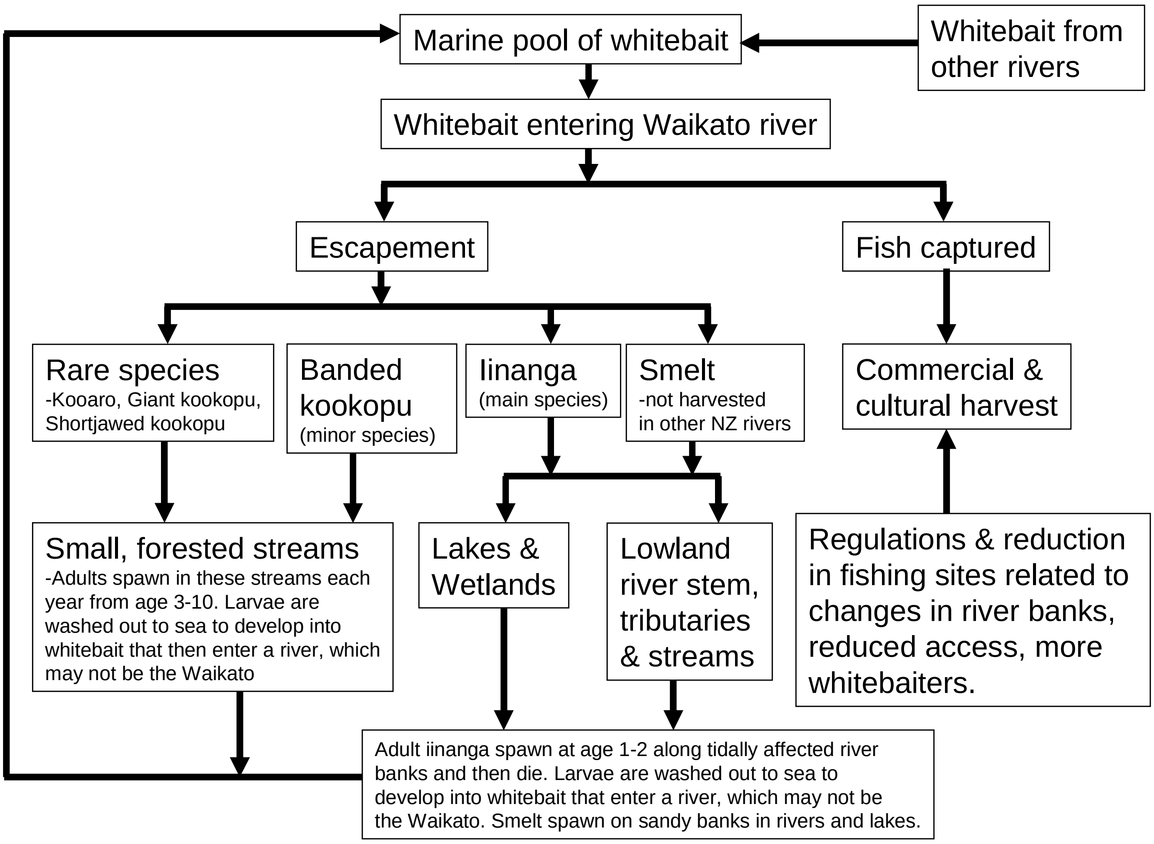

Figure 2: Conceptual model for the origin and supply of fish species sustaining the whitebait fishery in the Waikato River and the main controls/limits on whitebait fishing.

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

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

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

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

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

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

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

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

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

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

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

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

2. Goals for restoration

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

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

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

3. Actions

3.1 Restore iinanga spawning habitat

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

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

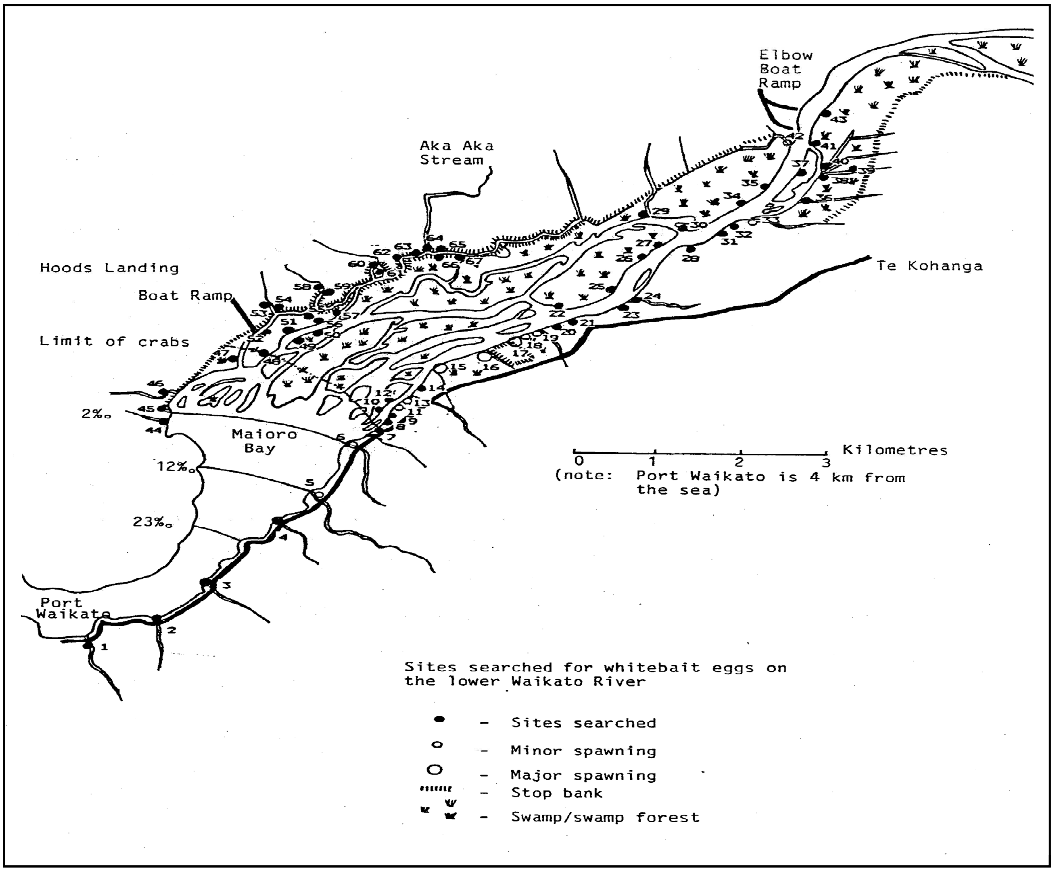

Figure 3: Map of lower Waikato River showing sites examined and found to contain iinanga eggs (Mitchell, 1990).

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

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

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

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

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

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

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

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

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

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

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

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

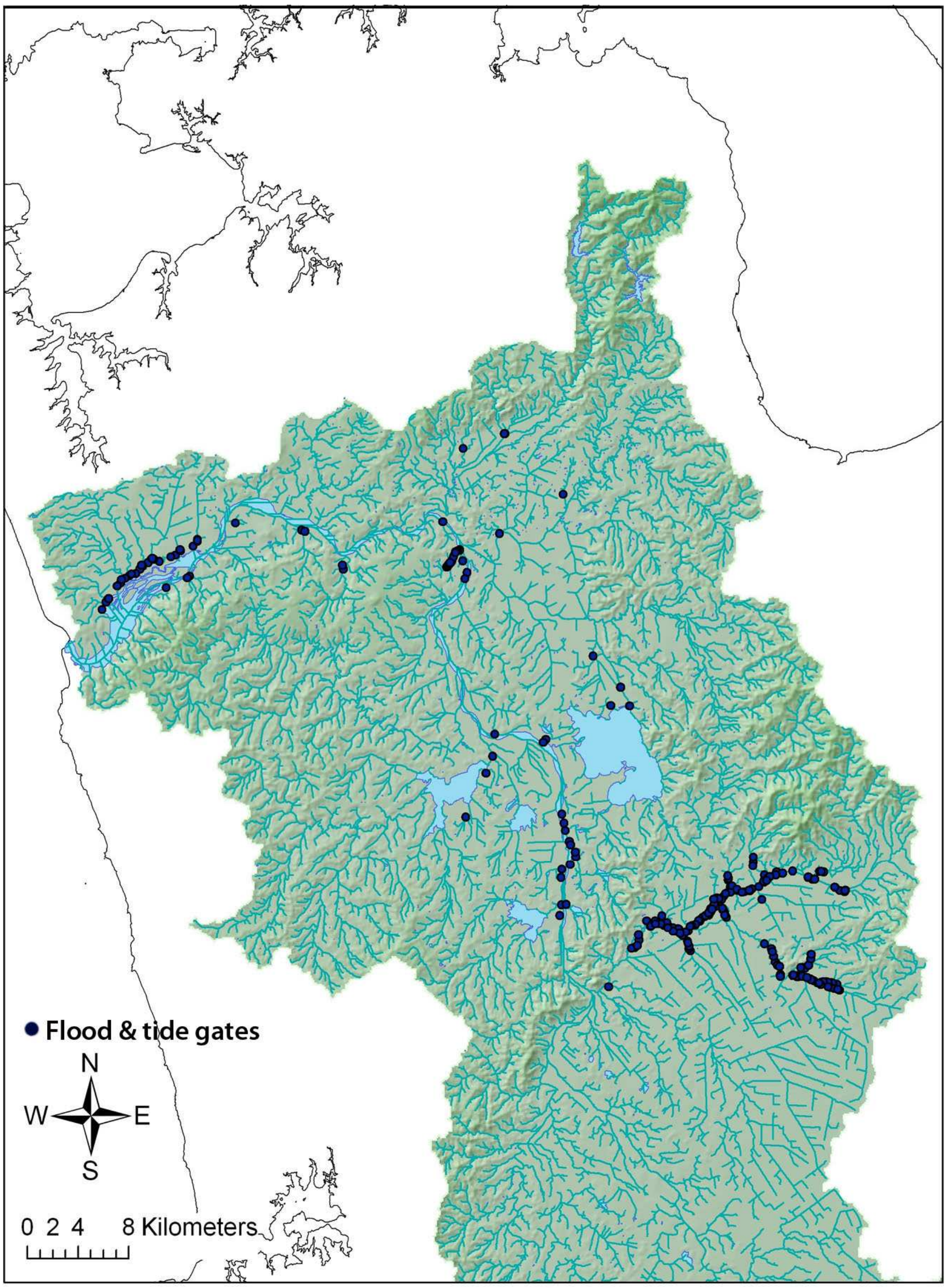

Figure 4: Location of known flood and tide gates in the lower Waikato River (data from Environment Waikato).

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

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

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

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

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

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

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

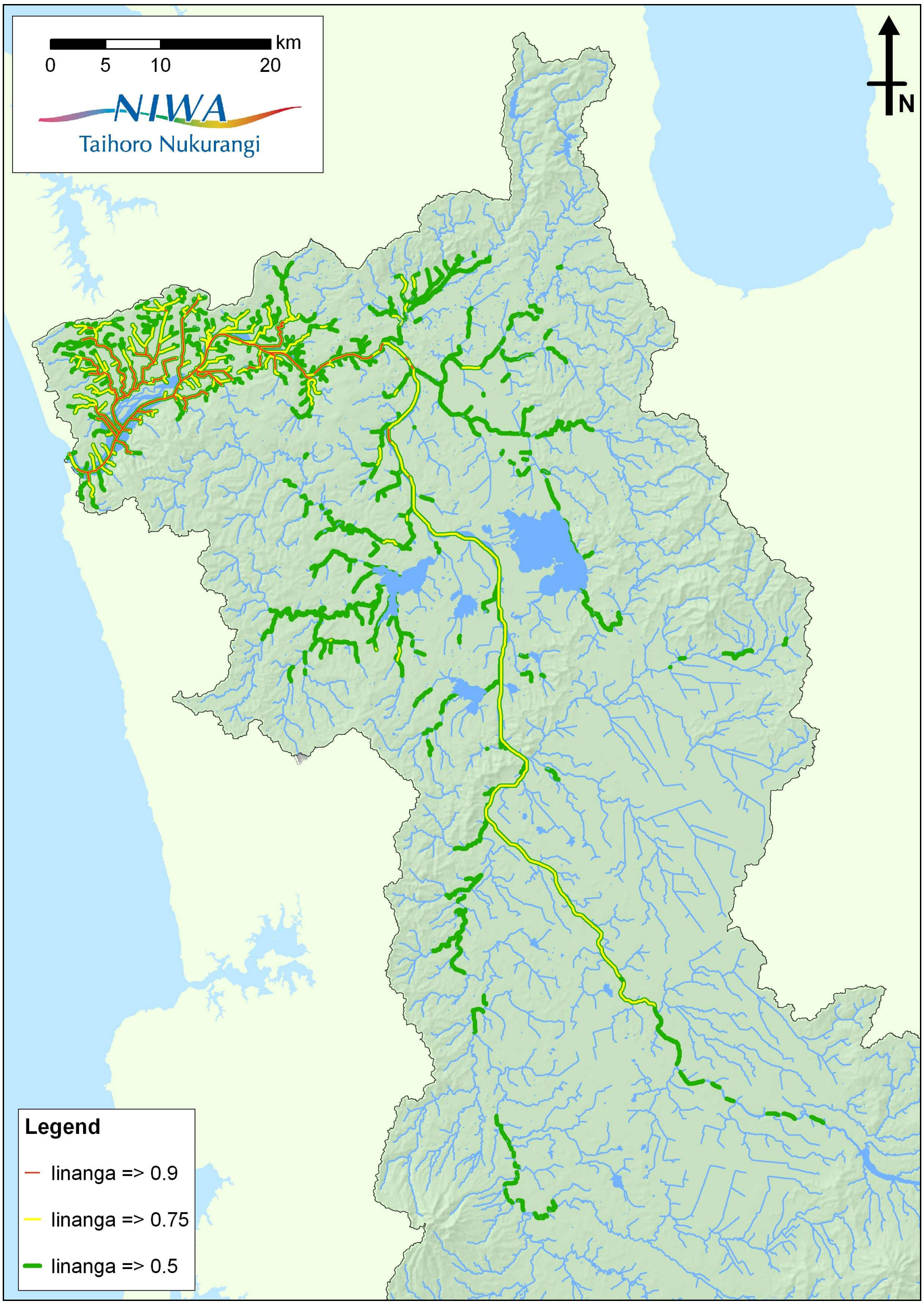

Figure 5: Location of stream habitat for iinanga in the Waikato River based on habitat models (Leathwick et al., 2005) and probability of occurrence. Prime habitat is marked red, optimal yellow, and good is green.

3.3 Restoration of adult iinanga to stream habitat

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

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

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

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

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

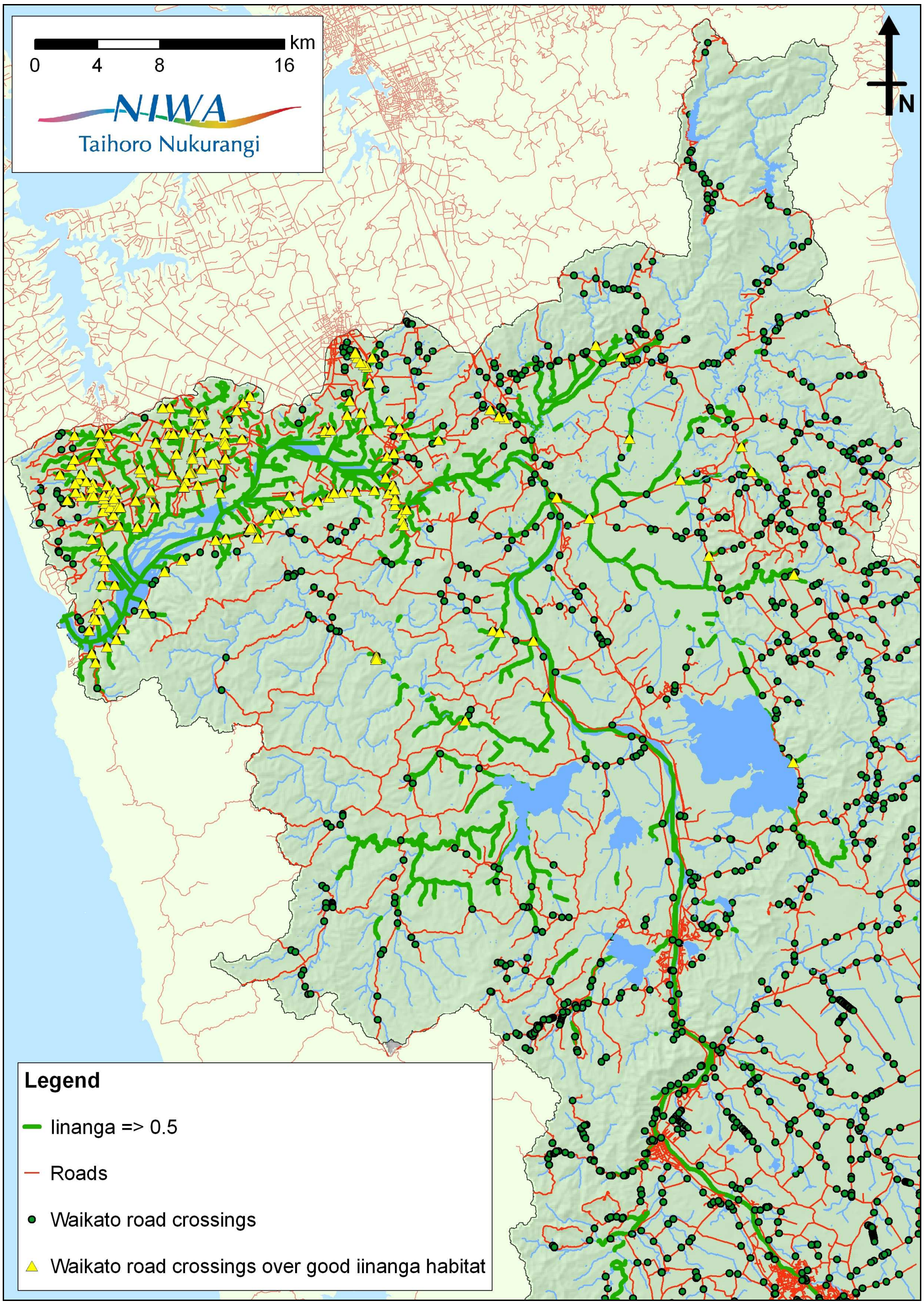

Figure 6: Map showing the intersection of streams and roads in the lower Waikato River and hence where culverts may occur (Note some streams will be crossed by bridges). The yellow triangles cross streams providing good iinanga habitat as identified by modelling.

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

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

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

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

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

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

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

3.4 Restoration of adult iinanga habitat in lakes

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

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

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

3.5 Restoration of habitat for banded kookopu and other whitebait species

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

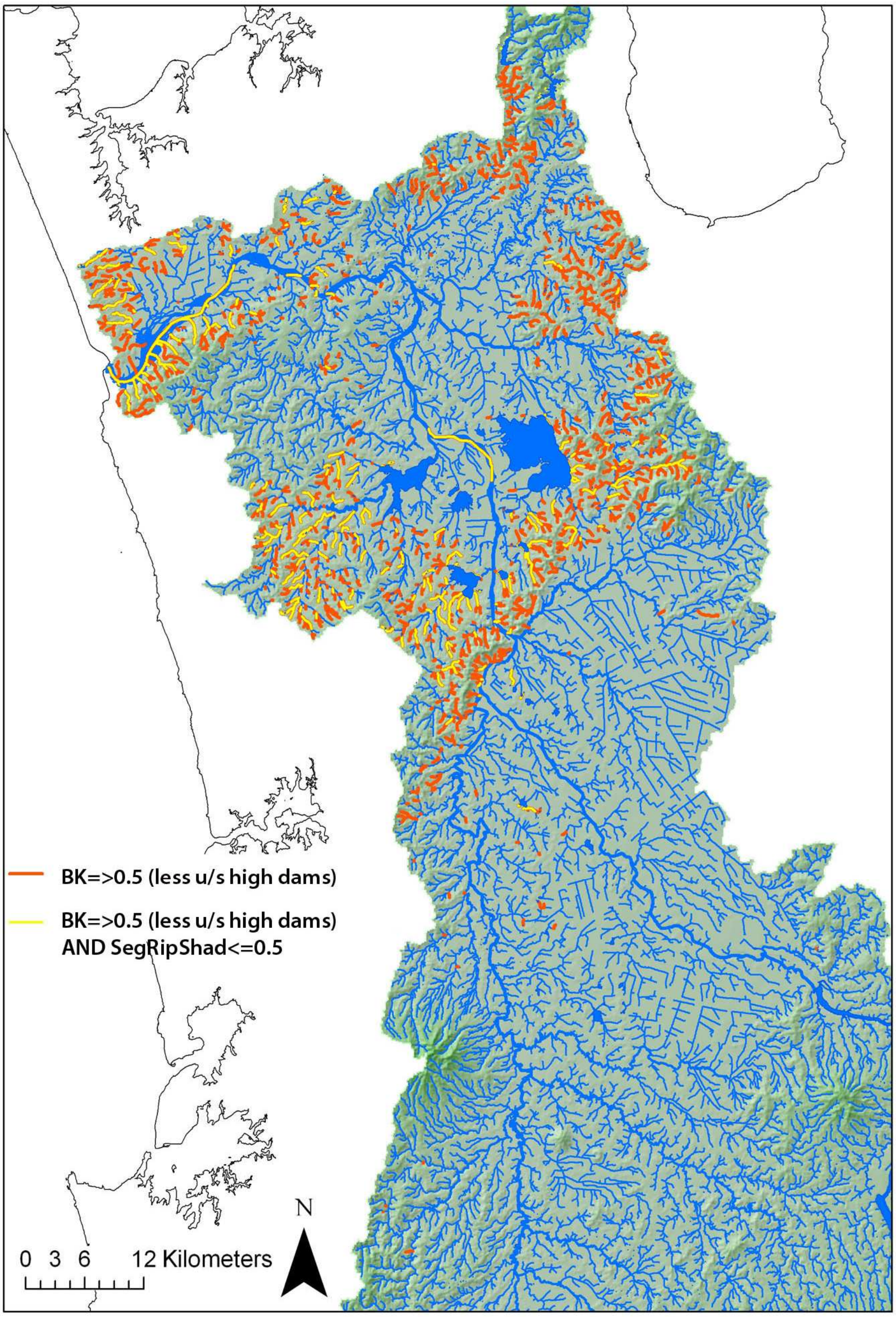

Figure 7: Location of good stream habitat for banded kookopu (BK) in the Waikato River as determined by modelling and the reaches within this where shade cover is sparse (yellow) versus abundant (red).

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

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

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

4. Outcomes

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

5. Risks and probability of success

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

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

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

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

6. Costs

6.1 Action A: Restoration of riverine spawning habitat

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

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

6.2 Action B: Restoration of stream-bank spawning habitat

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

6.3 Action C: Creation of new iinanga spawning habitat

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

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

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

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

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

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

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

6.6 Action G: Restoring cover for iinanga in streams

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

6.7 Action H: Reducing excessive weed growth in streams

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

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

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

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

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

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

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

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

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

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

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

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

7. Cost comparisons

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

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

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

Table 3: Actions ranked by total cost to full completion

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

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

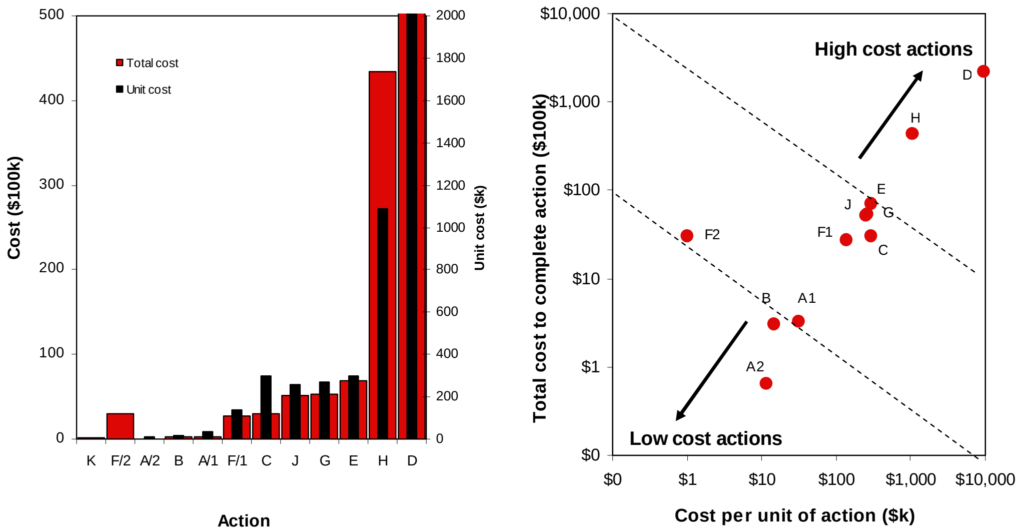

Figure 8: Comparison of the costs of each action based on both total (capital and operating) cost and the unit of action cost. In the right hand figure, the actions are plotted on logarithmic scales to encompass the wide variation in costs. The dashed lines separate actions with relatively high, medium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

8. Baseline/Monitoring restoration

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

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

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

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

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