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Status of koaro (*Galaxias brevipinnis)* populations in the Te Arawa lakes and options for their restoration

NIWA Client Report: HAM2008-100
August 2008

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Prepared for

Te Arawa Lakes Trust

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Contents

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Executive Summary

Landlocked koaro (*Galaxias brevipinnis*) was once the dominant fish species in most of the large, inland lakes of the central North Island and up until about 1900 koaro supported important Maori fisheries. However, these fish were decimated by the introduction of trout and later smelt. In addition, forest clearance has lead to the disappearance of koaro from many streams in the lakes' catchments. Today, the koaro is regarded as a taonga species with high heritage values, but it was also a key component of the lake's indigenous biodiversity, which has now been greatly reduced. Today, the historical values of this species are becoming more apparent, as is the extent of its decline, but the current status of koaro remains largely unknown and there is virtually no management to secure relict populations or to restore lost populations in streams, even though this is technically feasible. Although the Department of Conservation has a national role in the protection of indigenous species, the responsibility for native fish in many of the Rotorua lakes was vested in the Te Arawa Lake's Trust when ownership of the specific lakes was returned to Te Arawa. To properly exercise this responsibility, the Trust requires good information on the distribution, abundance and ecology of koaro. NIWA has endeavoured to provide this through its FRST funded programme on taonga species in the Rotorua lakes.

In this report, we provide the results of koaro surveys in the tributary streams of nearly all of the seventeen lakes centred around Rotorua. The results help define the current distribution and conservation status of koaro in each lake as well as regionally. The surveys increased the number of streams where koaro is known to be present from 12 to 16 (33% increase). However, the results also indicated that koaro is probably now extinct in ten lakes (i.e., Rotoehu, Rotoma, Rotokakahi, Rerewhakaaitu, Rotokawa, Okaro, Rotomahana, Ngahewa, Ngapouri, Tutaeinanga). Relict populations are present in a few streams in another four lakes (i.e., Rotorua, Rotoiti, Okareka, and Tarawera) and this species is only secure in Lake Okataina where it is still common in all six inlet streams. It is not present in Lake Tikitapu but it may never have existed here and its status in Lake Rotoatua is unknown.

It is apparent that management will be required to prevent the known relict stream populations from declining further and to restore koaro in streams where they are now absent, but where removal of trout and/or the creation of riparian buffers could help restore them. A number of stream sites (and small lakes) are therefore identified where protection or restoration could now be focussed and it is recommended that site specific restoration plans be drawn up for these sites, as done for koaro restoration in Lake Rotoaira.

1. Introduction

In pre-European times, the main fish harvested by Maori in the Rotorua lakes included the juvenile and adult stages of the koaro (*Galaxias brevipinnis*) termed 'inanga' and 'kokopu' respectively (Stafford 1986). These Maori fisheries were widespread in many of the Rotorua lakes up to the mid-1890s, and fishing grounds were clearly delineated, managed and even fought over (Hiroa 1921; Mair 1923; Stafford 1994; 1996). Between 1895 and 1950, the koaro populations were largely displaced by the introduction of both trout (mainly *Oncorhynchus mykis*) and smelt (*Retropinna retropinna*) to the lakes (Rowe 1990; 1993b). But degradation of lake and stream habitats will also have contributed to their decline (Rowe & Kusabs 2007).

Management of the Te Arawa lakes, and especially of traditional fisheries, was returned to Te Arawa in 2006 through settlement of the lake's bed ownership and associated legislation (Te Arawa Lakes Regulations 2006). This responsibility requires knowledge of the indigenous fish species present along with the tools available for their management. Te Arawa are steadily renewing their stewardship over historical fisheries and are now looking at ways of restoring species such as koura, kakahi and koaro. Young & Smale (2003) proposed the restoration of koaro in Lake Okataina by the elimination of trout. They envisaged that blocking trout access to all spawning streams would eventually result in the disappearance of trout from this lake. However, this is unlikely to be feasible in a lake of this size because trout will spawn on sandy shorelines when spawning streams are inaccessible (Penlington 1983). Furthermore, smelt can also displace koaro (Rowe 1993b) and would also need to be removed from the lake. This would be impractical in a lake of this size. A more realistic goal to conserve koaro in these lakes would be to remove both trout and smelt from small lakes such as Rotokawau, Okaro, Ngahewa, or Tikitapu, and/or to restore koaro in some of the tributary streams of the larger lakes, especially the streams that are of limited value for trout fishing and spawning. However, consideration of such management options to prevent the further extinctions of this 'taonga' species assumes that koaro historically occurred in all of these lakes and that relict populations still occur in some of the inlet streams thereby providing stocks for restoration.

Juvenile (migrant) koaro are adept climbers and are capable of moving up wetted, vertical rock faces and ascending large falls to the extent that they occur at altitudes of 1200 m and surpass even longfin eels in their ability to colonise inland waters. Koaro can therefore colonise most lakes that drain to the sea. The origin of koaro in the Rotorua lakes is therefore most likely to be due to a combination of natural recruitment from the sea into those lakes with river outlets (i.e., Rotoiti, Tarawera, Ngapouri and Ngahewa), followed by upstream colonisation of hydrologically connected lakes and

then finally stocking of the remaining lakes by early Maori settlers. Historic changes in lake levels and in lake drainage patterns will have affected hydrological connectivity. For example, although Okareka drains into Tarawera today (via the Waitangi stream), Okataina does not, even though it is likely to have drained into Tarawera for a period after these two lakes were formed around 5000-7000 years ago (Nairn 1981). Similarly, the water level in Lake Rotorua was 12 m above present levels as recently as 4000-8000 years ago when high rainfall occurred (Lowe & Green 1987; McGlone 1983). Lakes Rotoiti and Rotoehu were formed earlier, between 8,500 and 9000 years ago (Lowe & Green 1987), so if the water levels in Rotoiti and Rotoehu were also high at this time, these three lakes are likely to have been interconnected by surface flows. For example, a rise of about 5-6 m in the water level of Rotoehu today would result in a surface flow into Rotoiti. Given the historic changes in rainfall and lake levels and the highest point between these two lakes today, an historic surface water connection between them seems very likely. However, the current water level in Rotoma would have to have been c. 27 m higher to drain into Rotoehu, so an historic hydrological connection between Rotoma and Rotoehu is unlikely. However, Lakes Rerewhakaaitu and Rotomahana were formed more recently, around 700 ago, and were probably not connected to other lakes with drainage to the sea, so will not have been naturally colonised by koaro.

The eruption of Mount Tarawera in 1886 will have decimated many koaro populations in lakes centred around Lake Tarawera but remnant populations in some streams will have survived and allowed re-colonisation. It is also possible that migrants from the sea accessed Lake Tarawera after the eruption, even if such migrations are not possible today. Colonisation of lakes Ngapouri, Tutaeinanga and Ngahewa would have been possible via the Waikato River. Eels are thought to have once penetrated the Waikato River as far upstream as the Huka Falls (Downes 1918), even though few will have been able to pass the Maungatautari Falls (Hobbs 1940). If eels reached the Huka Falls, koaro will have too and some can be expected to have found their way into Lakes Ngapouri and Ngahewa. Alternatively, downstream migrant koaro from the abundant stocks in Lake Taupo can be expected to have spread downstream with some moving back upstream to establish landlocked populations in these two lakes.

The likely hypothetical pattern of natural colonisation of the lakes by koaro and by artificial stocking is shown in Figure 1.

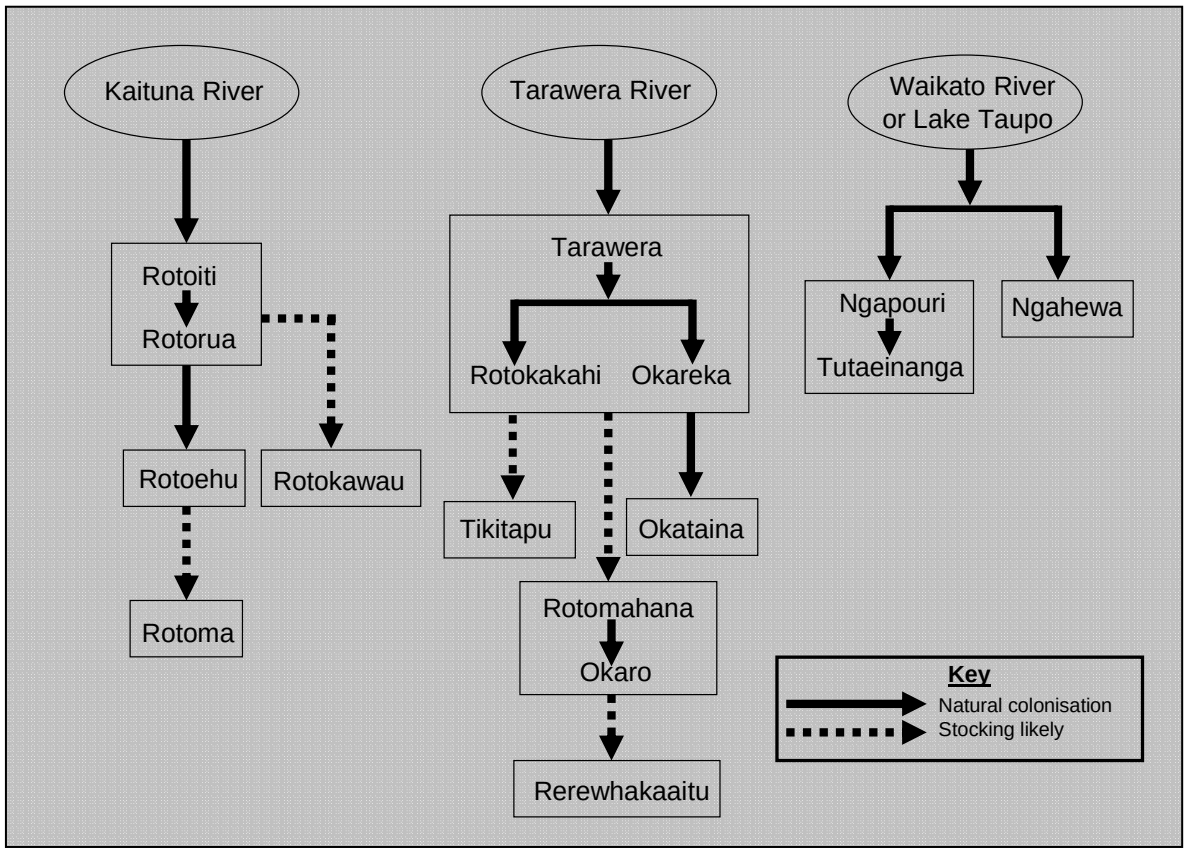

Figure 1: Hypothetical origin of koaro in the Rotorua lakes based on historical access to a lake via a river system, upstream migration of climbing juveniles to hydrologically connected lakes, or stocking of koaro by Maori into lakes with no hydrological connection to natural populations (boxes include lakes where stocks may be genetically similar because of natural movements between lakes).

Historic data in the New Zealand Freshwater Fish Database (NZFFD) showed that small, relict populations of koaro were present in some of the smaller (and hence mainly trout-free), bush-clad streams of the deeper lakes such as Rotoiti, Okataina, Okareka and Tarawera (Fig. 2). These stream populations are responsible for the continued recruitment of koaro to these lakes and some adult koaro still occur in low numbers close to the lake bottom in both Rotoiti (Rowe 1993a) and Okareka (pers. comm. K. Young, Dept. of Conservation, Rotorua). Koaro can therefore also be expected to occur close to the lake bottom in Okataina and Tarawera and there is evidence for this on echograms covering the deeper regions of these lakes. An exception to this generalisation is provided by Lake Rotoma. It is inconceivable that Rotoma alone would not have been stocked with koaro by early Maori settlers and that these fish would not have developed a self-reproducing population. But the koaro is now extinct here. This is also a deep lake, but unlike the other deep lakes, it lacks any stream large enough to support a resident population of koaro and as koaro are likely to require inlet streams for

spawning, this lack has probably lead to this species' extinction here when faced with the predatory onslaught of trout and then smelt. Koaro have also been historically recorded in lakes Rotokawau, Rotokakahi, and Rerewhakaaitu and relict populations may still be present in some of the tributary streams of these lakes.

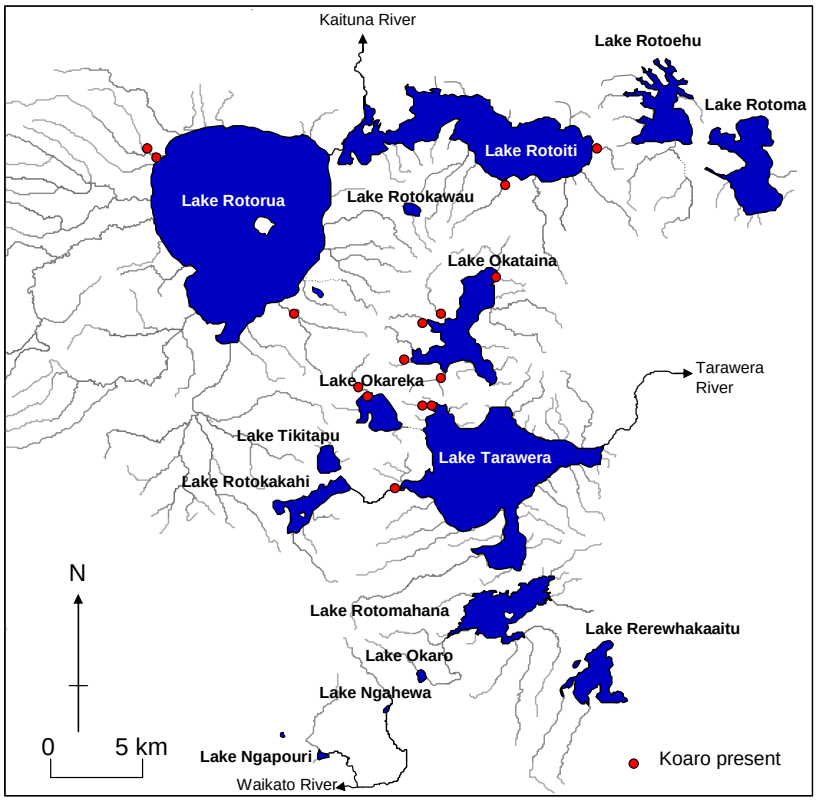

Figure 2: Distribution map for records of koaro in tributary streams of the Rotorua lakes prior to the 2007/2008 surveys (data from the New Zealand Freshwater Fish database).

Knowledge of the historic status of koaro in each of the Rotorua lakes was summarised by Rowe & Kusabs (2007) and is shown in Table 1. These data suggest that it is extinct in four lakes, rare in another five and that its status is unknown in five lakes. However, many streams which may still contain relict populations have not been surveyed yet. Hence the real distribution of koaro in the Rotorua lakes is poorly understood and needs to determined to identify the true status of this species in these lakes.

Table 1: Past and present status of koaro in the Rotorua lakes.

Lake name	Access to sea (river name)	Koaro status in the Rotorua lakes	
		Pre-1900	2005
Rotorua	Yes (Kaituna R.)	Abundant [4, 5, 9,11]	Rare, confined to streams [15,16]
Rotoiti	Yes (Kaituna R.)	Abundant [5, 9,12,14]	Rare, in 2 streams and in lake during winter[10,15,16]
Rotoehu	No	Abundant [3,7, 9,12,14]	Extinct [15,16]
Rotoma	No	Abundant [9,12]	Extinct [15,16]
Rotokawau	No	Abundant [6,15]	Status unknown
Okataina	No	Abundant [16]	Common in 5 bush-clad streams, some in lake [15]
Okareka	Yes (Tarawera R.)	Abundant [13,14,15]	Common in 1 bush-clad stream, some in lake [13,15]
Tarawera	Yes (Tarawera R)	Abundant [2, 8]	Rare in some bush-clad streams, some in lake [13,15]
Rotokakahi	Yes (Tarawera R.)	Abundant [8]	Status unknown
Tikitapu	No	No records	Never present, or extinct [15,16]
Rotomahana	No	Abundant [1, 9, 14]	Status unknown
Rerewhakaaitu	No	Abundant [14]	Extinct [15,16]
Okaro	No	Abundant [14]	Extinct[16]
Ngahewa	Yes (Waikato R.)	No records	Status unknown
Ngapouri	Yes (Waikato R.)	No records	Status unknown

Sources: [1]Dieffenbach (1843), [2]Bates (1870), [3]Talbot (1882), [4]Hiroa (1921), [5]Mair (1923), [6]Cowan (1926), [7]Pomare & Cowan (1930), [8]Papakura (1986), [9]Stafford (1967), [10]Rowe(1993a), [11]Stafford (1994), [12]Stafford (1996), [13]Young (2002), [14]Habib (2006), [15]New Zealand Freshwater Fish Database, [16]author's unpublished data.

Comprehensive surveys were therefore undertaken in 2007 and 2008 to identify the streams where populations of koaro are still present in order to determine the current status of koaro in the Te Arawa lakes. These surveys were also designed to identify stream populations that can be secured (e.g., through removal of trout, protection of riparian vegetation, and/or maintenance of stream habitat) to provide more sanctuaries for this species. This report presents the results of the surveys and identifies the relict populations that now require protection to conserve the lacustrine stocks of this species. In addition, it notes a number of streams where restoration of koaro could be readily carried out. The report therefore provides a current account of the management principles required to secure the status of this iconic, taonga species in the Te Arawa lakes.

2. Methods

Records of the fish species caught by electric fishing at stream sites in the Rotorua lakes catchments were retrieved from the New Zealand Freshwater Fish Database and inspected to identify the known locations for koaro. Streams for which no fish data existed were then identified on the NZMS 260, 1:50,000 topographic maps to indicate where further sampling was required. In all, 24 streams had been spot sampled by electric fishing before 2006 but there was no record for the other 115 streams in the NZFFD as at July 2006.

Koaro tend to inhabit small, first order streams that are heavily shaded by a bush canopy. They rarely occur in open streams in pastoral catchments and deforestation is thought to account for their general decline in New Zealand rivers (McDowall 1990). They are therefore unlikely to be found in open streams and surveys to detect the presence of adults need to focus on stream reaches beneath a bush canopy. Such reaches are often absent in the lower region of stream catchments and present only in the upper reaches. Therefore potential sampling sites need to include reaches in the upper regions of streams where a forest or riparian strip provides a bush canopy over the stream.

The NZMS 260 topographical map series covering the Te Arawa lakes were inspected to identify streams that had not been sampled using electric fishing and within these, sites beneath a bush catchment. Many of the sites found proved to be difficult to access because they lie within private property and there is no vehicle access to them. However, many of the sites were accessible and were therefore sampled during 2007 and 2008. Although many inlet streams are shown on the NZMS maps, many of these are small and so may dry out during summer months. Inspections were therefore carried out in summer to distinguish the perennial from the ephemeral streams and to sample the perennial streams.

Each site was electric fished (single pass) in an upstream direction with approximately 50 m (minimum) of stream reach being sampled. Electric fishing by experienced operators allows the sampling of fish with minimal harm. Fish are temporarily stunned by the current and are readily netted from the stream using metal-meshed dip-nets, which isolate them from the current. They recover immediately and are placed in a collecting bucket for later processing. Any fish present within a sampled reach were identified to species level and their total length measured before being returned to the water. The fish species present in the streams of the Te Arawa lakes include rainbow trout, common bullies, smelt, koaro, gambusia (in some lakes), and goldfish.

The stream locations where koaro were present or absent (including streams which were dry) were then mapped to indicate the number of tributaries where this species still occurs in each lake. A number of the less accessible sites could not be sampled and therefore constitute 'gaps' in the record. These sites are identified as 'not yet sampled' and indicate where future sampling needs to be directed.

Streams where good habitat for koaro was present and where large reaches could be amenable to restoration and protection were also identified. The criteria for these included; (a) sites where both koaro and trout were present but where trout removal would be feasible and not affect recruitment significantly, (b) sites lacking koaro but where restocking could establish viable populations, (c) sites where koaro were common but where future changes to land or water use may threaten the viability of these populations. Although juvenile trout and adult koaro co-occur in many streams, koaro tend to be scarce in streams where trout density is high and are only abundant above falls that are inaccessible to trout (Rowe & Konui 2007). Removal of trout is therefore a viable method for increasing the stocks of koaro and can be achieved by firstly installing a barrier to their upstream migration below the reach to be restored, and secondly by removing all trout above this barrier. Rowe et al. (2007) described a number of barrier types that can be used to prevent trout movement upstream and also described successful uses of such technology to restore native fish affected by trout. The optimal methods for protecting or restoring koaro in streams within the Te Arawa lakes catchments were therefore identified for each location that met the above criteria and are listed to provide the basis for a site-specific restoration management plan.

3. Distribution and status of koaro

The number of inlet streams entering each lake on the NZMS 260 topographical maps is shown in Table 2. Of the 139 inlet streams identified on these maps, 30 were not checked because of access difficulties, 69 were found to be dry during summer months and 40 had a water flow when visited, so were sampled. The total number of streams checked for fish was therefore increased from 24 to 40. In the streams where a flow was present, we found four new or unrecorded populations of koaro; two in Lake Okataina, one in Lake Rotorua and one in Lake Tarawera. This increases the number of stream sites where adult koaro are present in the Te Arawa lakes from 12 to 16 (i.e., a 33% increase).

Table 2: Number of streams entering each lake and the number sampled as at July 2006 and July 2008.

No.	Lake name	Marked on NZMS 260 maps	Not sampled to date	Known to be dry in summer	Sampled before 2006 (NZFFD record)	Sampled to date (July 2008)	Sites where adult koaro occur
1	Rotorua	21	10	3	7	8	4
2	Rotoiti	19	8	5	2	6	2
3	Rotoehu	14	0	11	3	3	0
4	Rotoma	10	1	8	1	1	0
5	Okataina	18	0	12	4	6	6
6	Rotokawau	1	1	0	0	0	-
7	Rotoatua	2	1	0	0	1	-
8	Tikitapu	4	0	4	0	0	0
9	Okareka	3	1	1	1	1	1
10	Tarawera	26	4	16	3	6	3
11	Rotokakahi	3	0	1	0	2	0
12	Rotomahana	9	1	6	0	2	0
13	Rerewhakaaitu	3	1	0	0	2	0
14	Okaro	2	0	1	1	1	0
15	Ngahewa	1	0	0	1	1	0
16	Ngapouri	2	1	1	1	0	0
17	Tutaeinanga	1	1	0	0	0	0
	Total	**139**	**30**	**69**	**24**	**40**	**16**

Not surprisingly, three of these new populations were associated with streams where the water flow is mainly from springs as against catchment rainfall. Large koaro populations in pre-European times were often associated with large springs (Rowe et al. 2002) and in Lake Rotoaira today, streams where koaro are still common are also associated with springs (Rowe & Konui 2007). Reasons for the strong association between koaro and spring-fed tributary streams in lakes are unknown, but are likely to include the colder water. Koaro is one of the more temperature sensitive of the native fish species, preferring waters around 13ºC (Richardson et al. 1994) and the temperature of streams fed mostly by cold springs is often close to this.

3.1 Lake Rotorua

Stream sites sampled to date in the Lake Rotorua catchment are shown in Figure 3. In total, over 35 sites have now been sampled (27 in this survey). Koaro had been previously reported in the database only from the Awahou and Waingaehe Streams. We recorded the presence of adults in the Hamurana Stream and in the Komutumutu Stream, a major tributary of the Waititi where good habitat for koaro occurs. A number of stream sites were not able to be sampled in Lake Rotorua, especially on the eastern side of the lake and, if these are not dry during summer months, koaro may also be present in some of them, especially if they are spring-fed. Most of these are accessible only via private property.

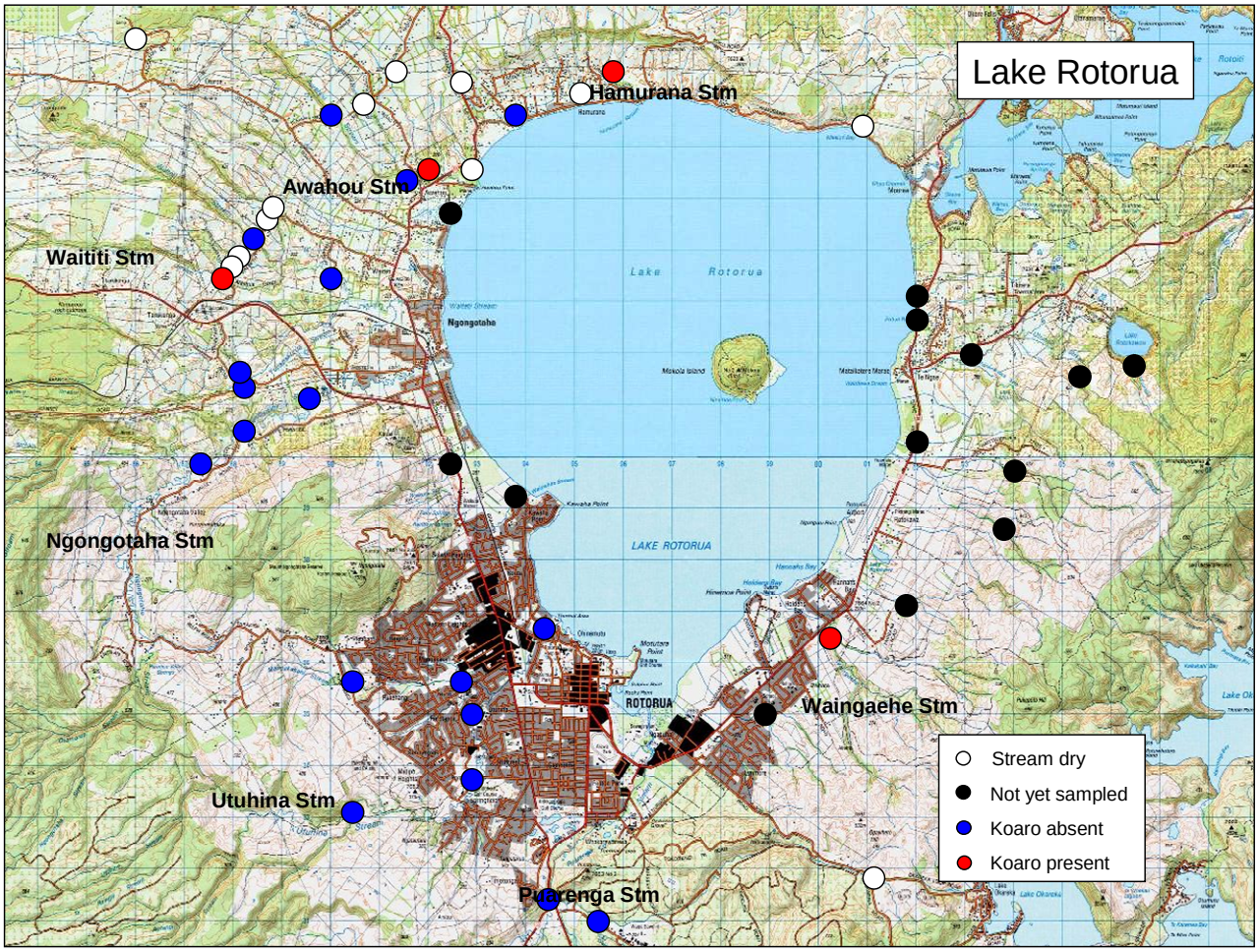

Figure 3: Presence or absence of koaro in the inlet streams of Lake Rotorua and the location of streams still to be checked.

A number of sites in the Puarenga Stream were sampled. These all contained trout and no koaro were found. The upper reaches of the Ngongotaha and Utuhina are both bush-clad and relatively steep so provide good habitat for koaro. Trout dominate the lower reaches of these streams and so exclude koaro, but trout may be absent or scarce in the upper reaches especially above large falls that may have prevented their upstream migration. If so, it is possible that koaro will occur in these upper reaches and this needs to be checked.

Koaro were once abundant in Lake Rotorua and were extensively harvested in the lake as well as during their spawning migration into and out of the Hamurana Springs (Rowe & Kusabs 2007). It is clear that they will have been the dominant fish in all tributary streams prior to the arrival of trout. The results obtained to date indicate that they are now confined to just four streams in Lake Rotorua and even here they are scarce. Clearly, their continued presence in Lake Rotorua stream is precarious.

3.2 Lake Rotoiti

Koaro are now present in only two streams in Lake Rotoiti (Ruato and Waiiti[1]). Juveniles were found at the entrances of two other streams (Fig. 4) but habitat for adult koaro in these streams is minimal so adult populations are unlikely to be present. Koaro were absent from the Te Toroa Stream, which is one of the main tributaries and one of the main trout spawning streams in Lake Rotoiti. Although the upper reaches are yet to be checked, it seems unlikely that koaro will occur in this water course because of the prevalence of trout. The Hauparu Stream has not been sampled to date and is also used by trout for spawning. Given its similarity to Te Toroa Stream koaro are unlikely to be present here.

A number of streams draining into the southwestern side of Rotoiti still need to be sampled to confirm the absence of koaro. Many of these can be expected to be either dry in summer or affected by geothermal waters so it is unlikely that koaro will be present. Similarly, two small ponds in the Lake Rotoiti catchment have not been sampled to date, but it is also unlikely that koaro will be present in these as the water quality is low. In 1985, adult koaro were still relatively common in the deeper waters of Lake Rotoiti (Rowe 1993). Given that this fish spawns in streams, it is likely that these lacustrine kokopu were the product of the spawning populations of koaro still present in the Ruato and Waiiti Streams. In summer, these adult koaro in the lake are forced into the warmer, shallower waters by de-oxygenation of the hypolimnion in Lake Rotoiti. They then become more vulnerable to predation by shags and trout, and more prone to

[1] Adults are found in a short section of this stream just below the spring head (pers. comm., Ian Kusabs).

disease and mortality because of the warmer and less oxygenated water. The removal of a deep water refuge for this species during the warmer summer months adds another stress to the relict populations in this lake.

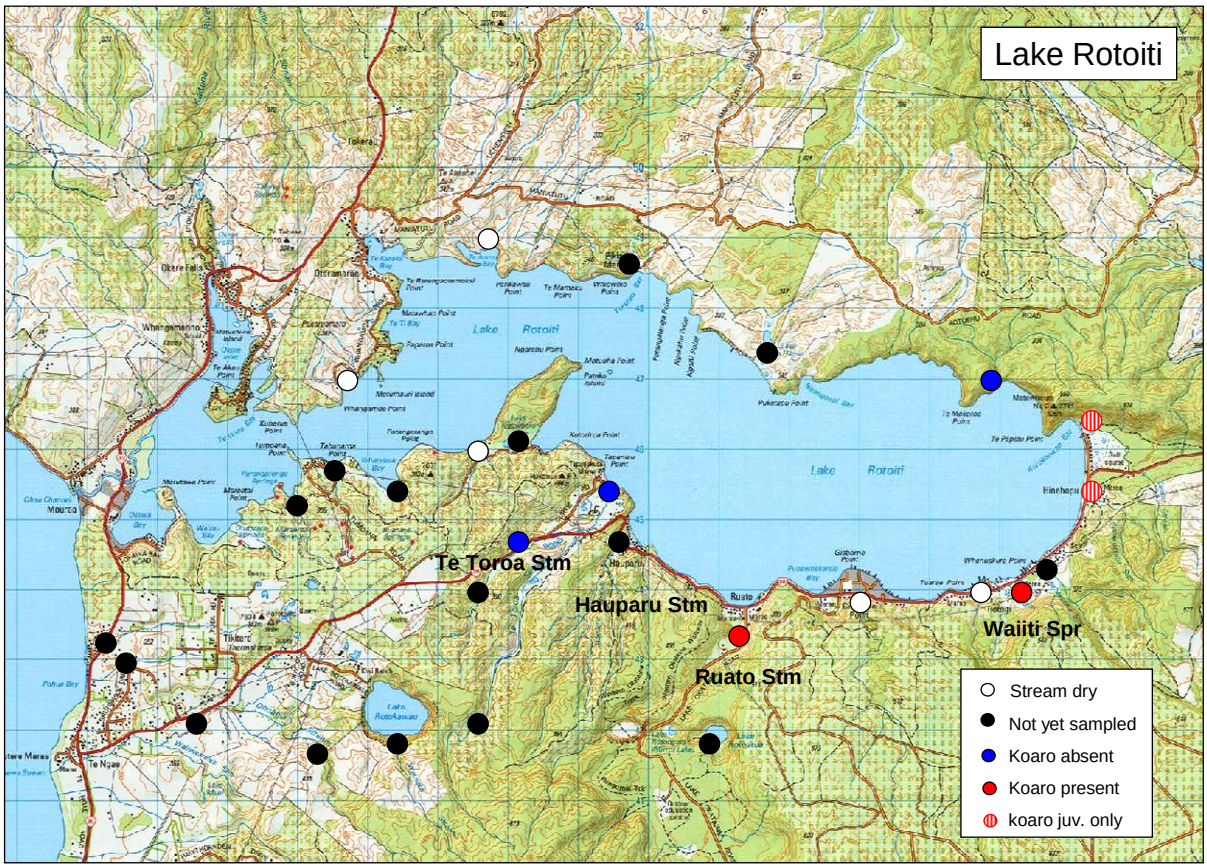

Figure 4: Presence or absence of koaro in the inlet streams of Lake Rotoiti and the location of streams still to be checked.

3.3 Lake Rotoehu

Most of the streams in Lake Rotoehu shown on the NZMS topographical map are non-existent or dry for much of the year (Fig. 5). As a consequence, there are only three main inlet streams (excluding the warm geothermal input from the Waitangi Soda Spring). All were dominated by juvenile trout and no koaro were found.

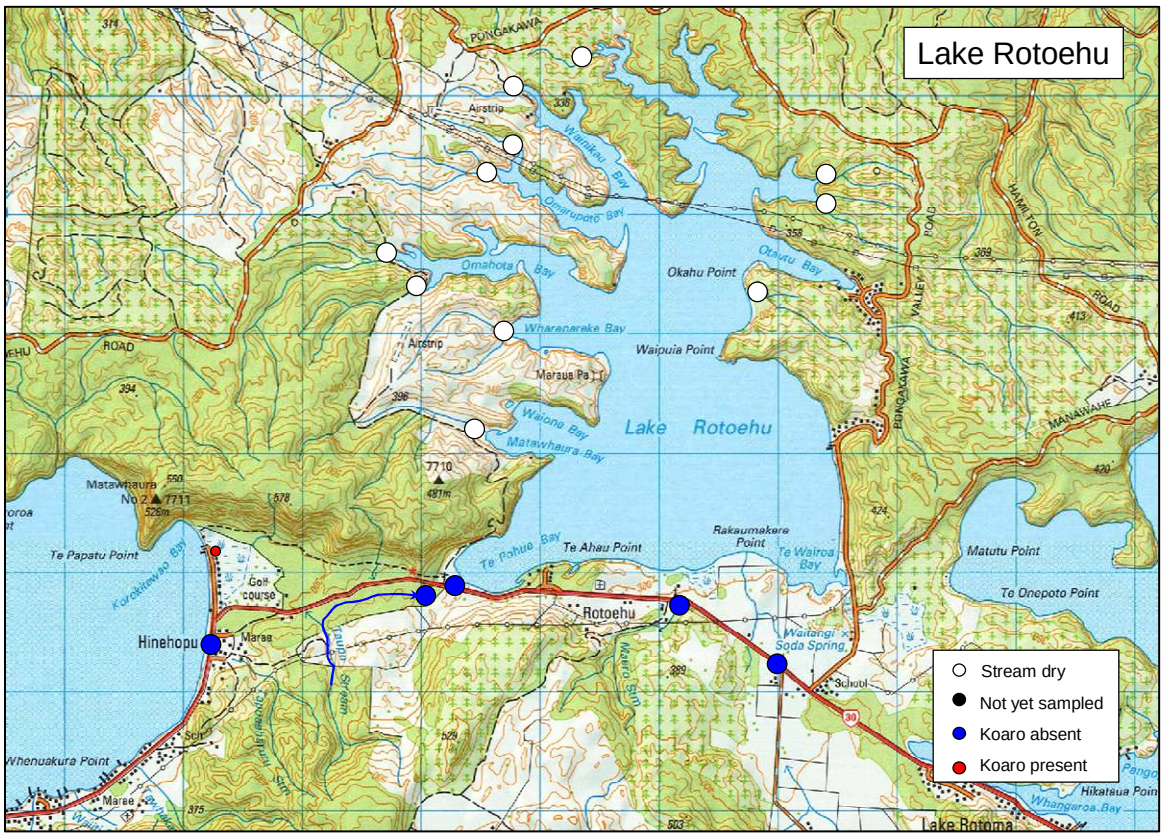

Figure 5: Presence or absence of koaro in the inlet streams of Lake Rotoehu and the location of streams still to be checked.

Koaro were historically abundant in this lake so this species will have either been stocked into it by early Maori settlers and subsequently established a breeding population, or accessed it via a link to Lake Rotoiti. The lakes may have been historically interconnected when water levels in Rotorua/Rotoiti were much higher than at present, but Rotoehu is not hydrologically linked to Rotoiti today. Clearly, trout have now replaced the spawning populations of koaro in the few perennial inlet streams and both trout and smelt have combined to displace koaro in the lake. Without any refugia provided by deep water or cold springs, the koaro is now extinct in this lake.

3.4 Lake Rotoma

There are no major inlet streams flowing into Lake Rotoma and no outlet so it too will have been historically stocked with koaro by Maori. A small breeding population would have established in the inlet streams and supplied the lake. The largest stream, known locally as Fish Creek, is short and is now used primarily by rainbow trout for spawning (Fig. 6). Most other streams are dry during summer months. One stream has yet to be checked for koaro, and if it is not present here, this species can be considered extinct in this lake as well.

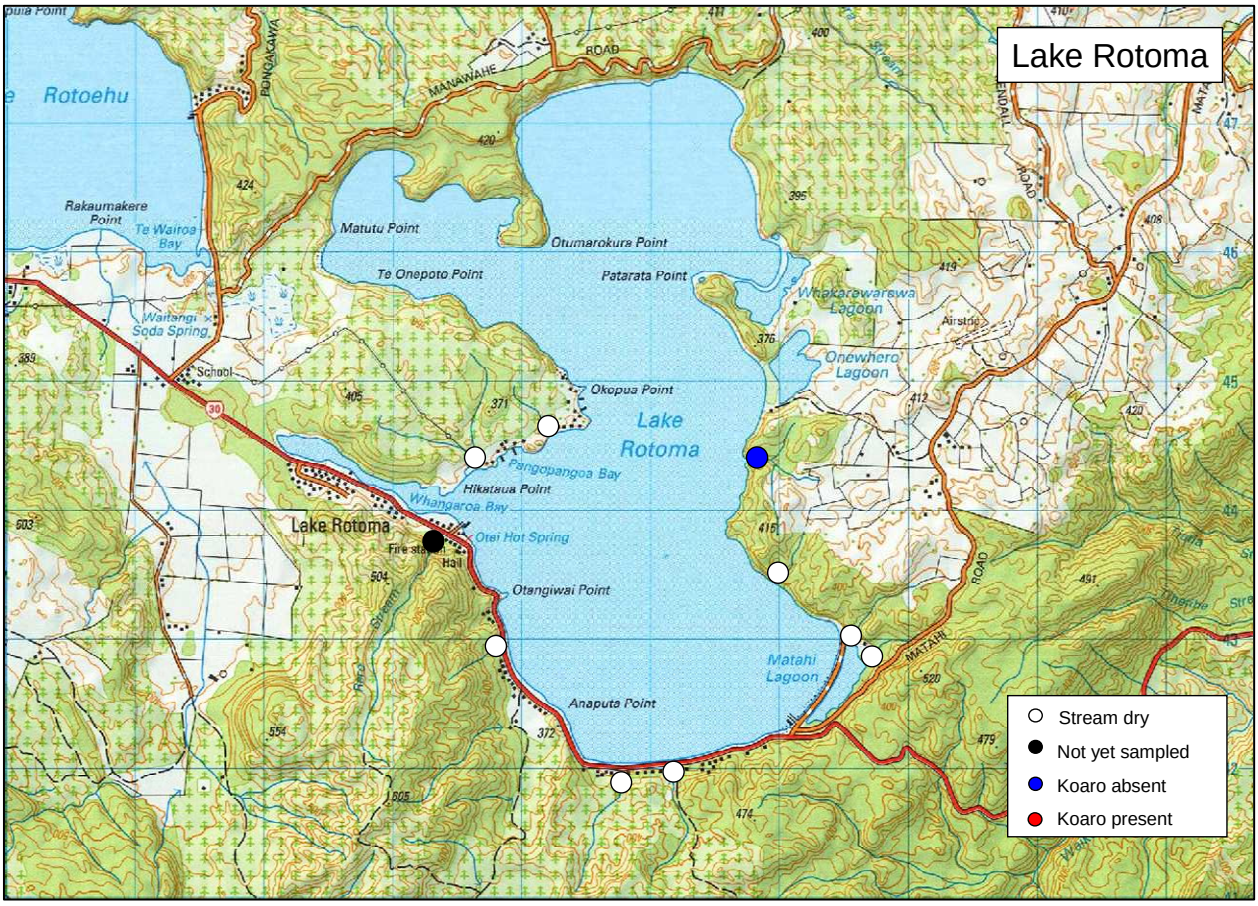

Figure 6: Presence or absence of koaro in the inlet streams of Lake Rotoma and the location of streams still to be checked.

3.5 Lakes Rotokawau and Rotoatua

Koaro were historically reported (NZFFD records) from Lake Rotokawau and a relict population could still occur in the Waimata Stream, which is yet to be checked (Fig. 7). As there is no lake outlet, koaro will have been stocked into it by Maori and established a self-recruiting population. Trout were once stocked here but have now died out because there is no spawning habitat in the lake and a small fall prevents their access to the Waimata Stream. Trout predation will have reduced the koaro stocks in the lake. However, it is a deep water lake (allowing adult koaro to avoid trout predation by occupying deep water) and it has a small inlet stream that is inaccessible to trout. This stream would have allowed a relict population of koaro to persist. But smelt are present in this lake, and even though trout are now gone, the smelt will have competed with juvenile koaro for planktonic food and preyed on the larvae. Koaro may therefore be extinct here but the inlet stream needs to be checked to determine this.

Lake Rotoatua has no surface inlet stream (Fig. 7) however, two streams straddle the Outdoor Education Centre on Okataina Road and disappear underground south-west of this lake. They may provide a subterranean water source to this lake. There were no fish in the northern stream but the lake and southern stream are yet to be checked. It is not known whether this lake was ever stocked with koaro.

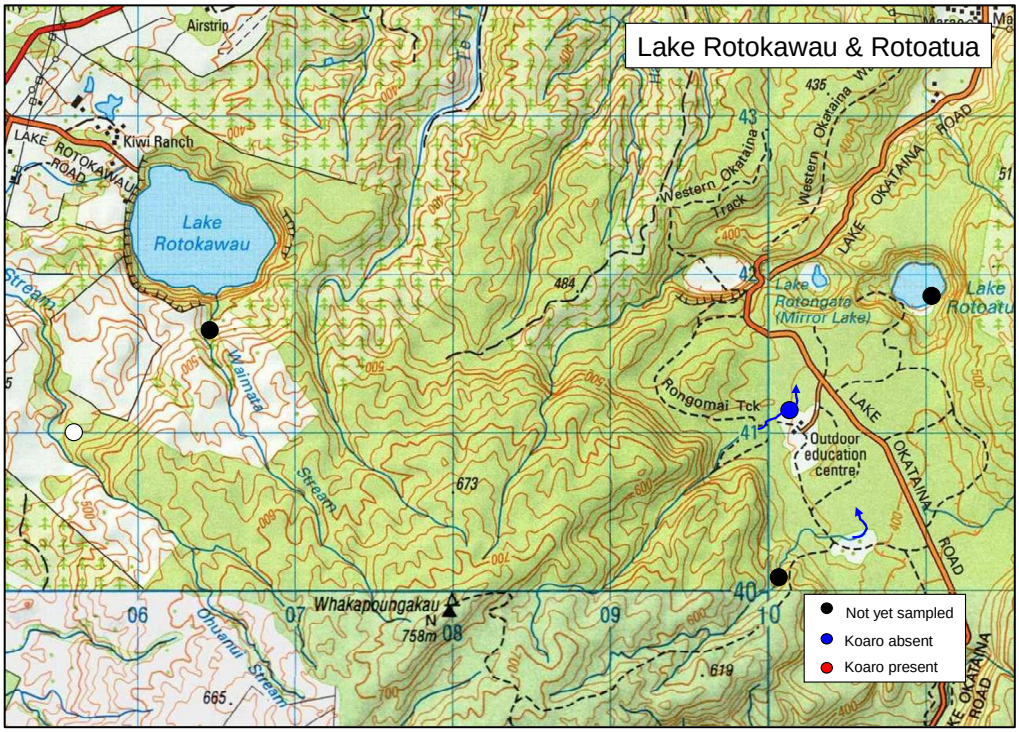

Figure 7: Presence or absence of koaro in the inlet streams of lakes Rotokawau and Rotoatua and the location of streams still to be checked.

3.6 Lake Okataina

Koaro were present in all the tributary streams flowing into Lake Okataina (Fig. 8). Two of these (the Log Pool Stream and the unnamed stream that enters the lake north of Motuwhetero Island) had not been surveyed before for koaro. Juvenile trout also occur in these tributaries but the streams are all small (less than 1 m wide) so do not provide much habitat for trout spawning or juvenile rearing. Consequently juvenile trout are relatively scarce in these streams and this may allow koaro to persist in them. All marked tributaries on the eastern side of the lake were dry and the largest tributary entering the lake is the spring-fed 'Log pool' stream. This stream is likely to be the major spawning site for trout in this lake. It contains many koaro, possibly because its bouldery substrate, wide range of flow types and variations in water depth diversify habitat and allow these two species to partition the habitat. In addition, only koaro will occur in the stream beyond the highest point trout can reach.

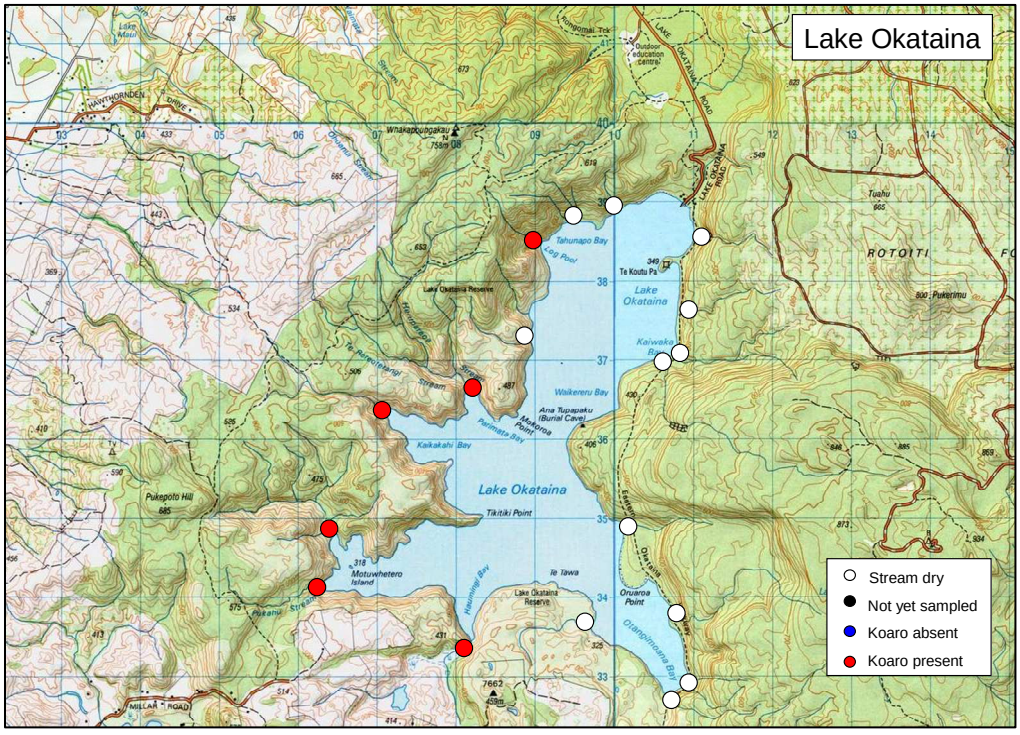

Figure 8: Presence or absence of koaro in the inlet streams of Lake Okataina and the location of streams still to be checked.

Koaro are common in all of the perennial tributaries in Lake Okataina and so this species has a much higher presence here than in all other Te Arawa lakes. The presence of good stream populations is likely to depend mainly on the fact that they are all in relatively unmodified catchments and the streams are small and steep such that trout density is not high. In addition, some adult koaro can be expected in the lake in deep water (>50-80 m) where trout seldom forage (Rowe 1993a).

3.7 Lake Tikitapu

There are four tributary streams that enter Lake Tikitapu (Fig. 9) but all are dry or non-existent. It is not known whether koaro ever occurred in this lake.

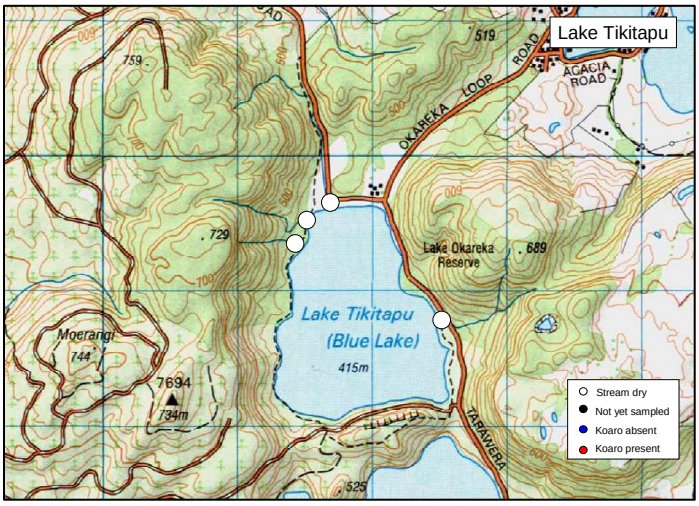

Figure 9: Sites inspected to determine the status of the inlet streams of Lake Tikitapu.

3.8 Lake Okareka

Lake Okareka drains into Lake Tarawera and so is accessible to upstream migrant koaro from Lake Tarawera. Koaro still occur in this lake but are currently confined to the northern (Boyes Beach) stream that runs under Millar Road (Fig. 10). The inlet stream beside Okareka Loop Road was dry. The stream on the lake's southern shore was not checked but is also likely to be dry and it has no riparian cover needed to sustain koaro.

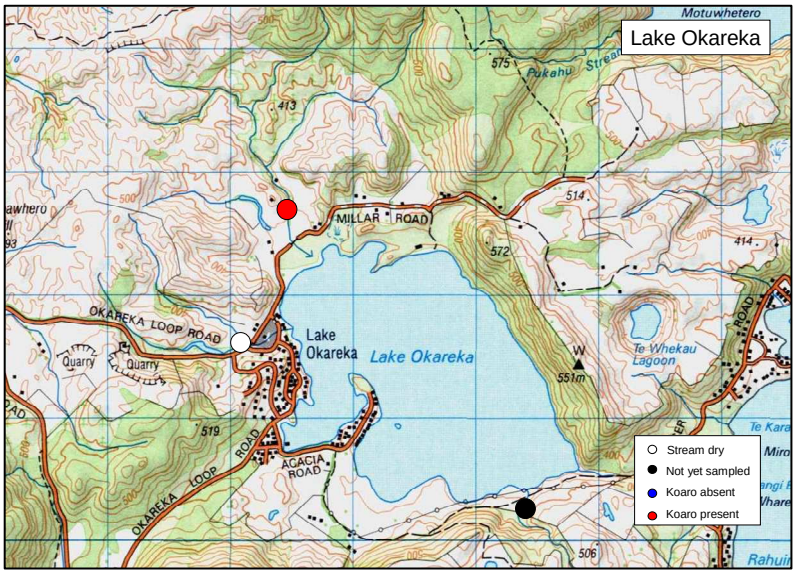

Figure 10: Presence or absence of koaro in the inlet streams of Lake Okareka and the location of streams still to be checked.

3.9 Lake Tarawera

Koaro (and eels) are likely to have initially gained access to Lake Tarawera via the lake outlet and the Tarawera River and koaro will have established a landlocked population after access was prevented (e.g., by tectonic changes) whereas the eels will have died out. Failing this koaro will have been stocked into Tarawera from other local lakes. Koaro were abundant in this lake in pre-European times but stocks will have been devastated by the Tarawera eruption in 1886. This changed the lake level and outlet and may have reduced or stopped any migrations of juveniles from the sea via the Tarawera River. Koaro are still persist in Lake Tarawera today. Populations are now confined to three of the eight streams that have been checked and which flow into the lake during summer months (Fig. 11). Most of the marked tributary streams entering this lake, especially those on the eastern side of the lake were either dry or non-existent as occurred for Lake Okataina. However, four streams still need to be physically checked. Koaro will have once been abundant in the Wairau and Wairoa Streams as they provide good habitat for this species. Both streams are now major spawning and rearing tributaries for trout and koaro were absent in both.

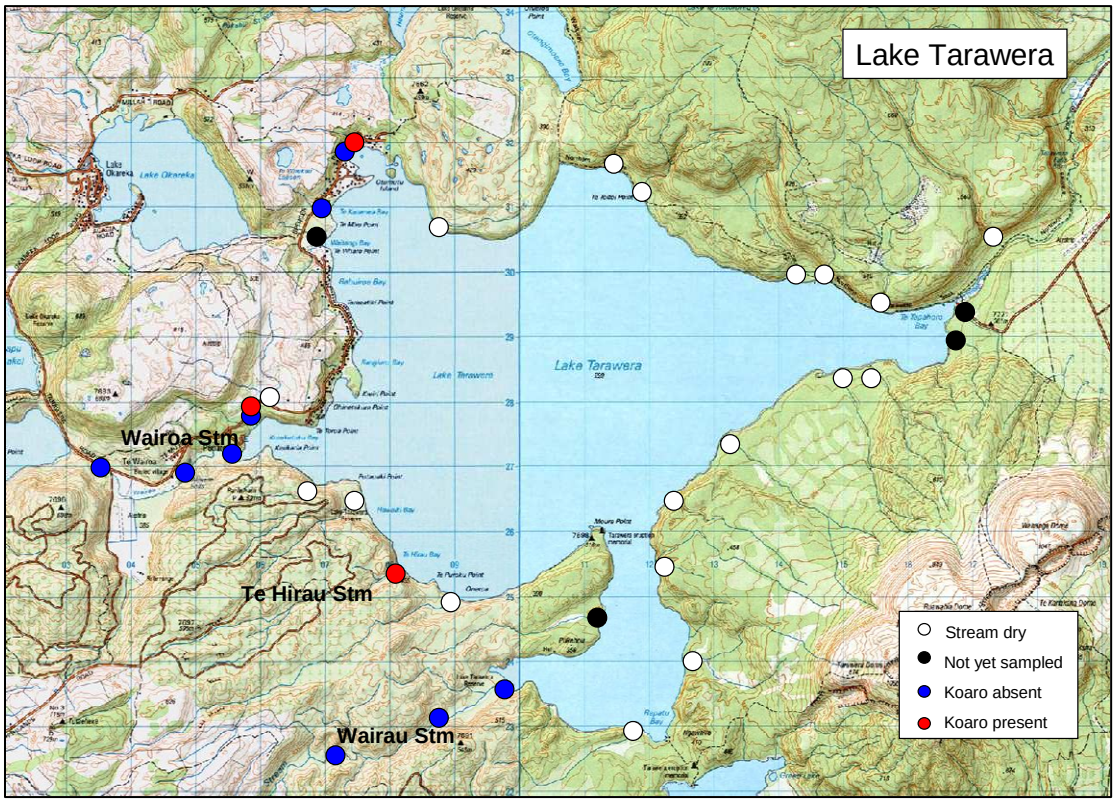

Figure 11: Presence or absence of koaro in the inlet streams of Lake Tarawera and the location of streams still to be checked.

A new relict population was found in the Te Hirau Bay Stream (Fig. 12). The Te Hirau Bay Stream population represents a major find and can be considered the last 'reservoir' for koaro in this lake. However, the Waitangi Stream, which allows water from Lake Okareka to enter Lake Tarawera needs to be checked as it too may harbour a population of koaro.

Figure 12: A koaro from Te Hirau Stream in Lake Tarawera (top) and the site where it was captured from (bottom).

3.10 Lake Rotokakahi

This lake is connected to Tarawera by the Wairoa Stream and the falls on this stream would be readily surmounted by juvenile koaro. Hence, Lake Rotokakahi will, like Lake Okareka, have been colonised by upstream migrants from Lake Tarawera. Historically, koaro provided a major fishery for Maori in this lake, but the koaro is now probably extinct. Of the three streams entering this lake, trout occurred in two and one was dry (Fig. 13).

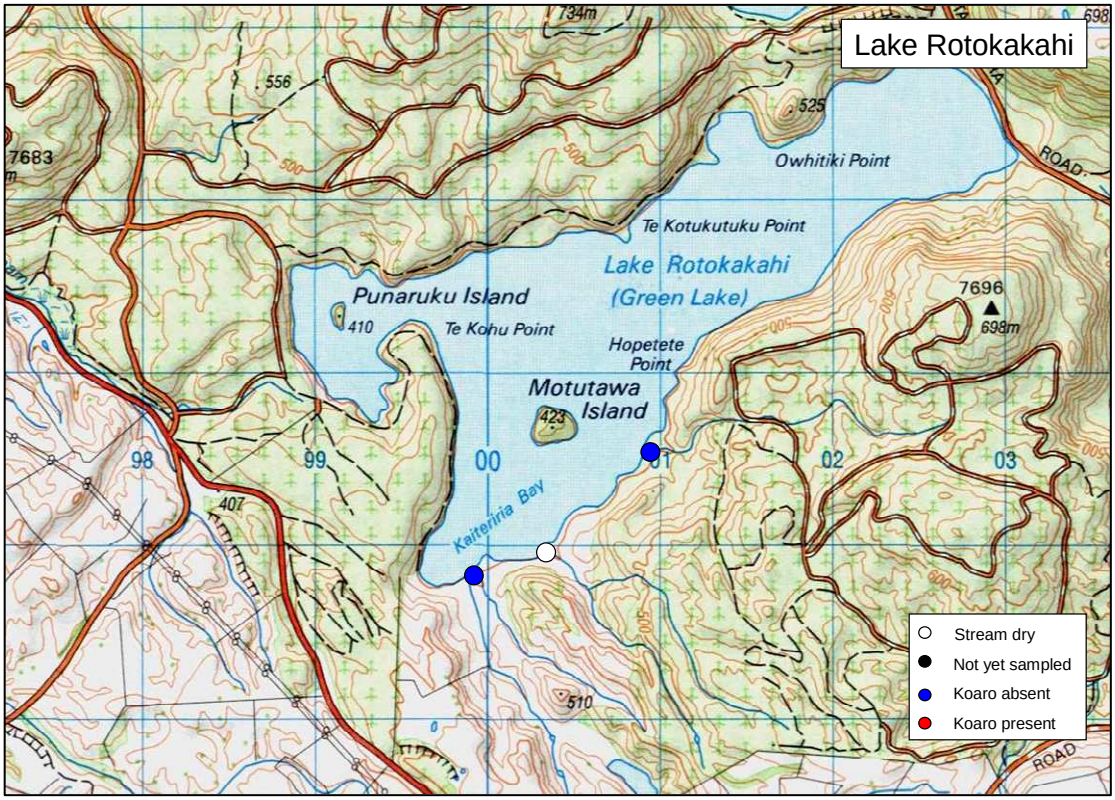

Figure 13: Presence or absence of koaro in the inlet streams of Lake Rotokakahi and the location of streams still to be checked.

3.11 Lake Rotomahana

Eight of the nine streams entering this lake were checked and only two were flowing. No koaro were found in these (Fig. 14). The remaining inlet stream is largely affected by geothermal inputs and so does not provide suitable habitat for this fish. However, a major branch of this (the Haumi Stream) drains Lake Okaro and suitable koaro habitat may occur here if it is not dominated by trout. It therefore needs to be checked.

Lake Rotomahana was extensively modified as a consequence of the Tarawera eruption and this alone may well account for the current absence of koaro here.

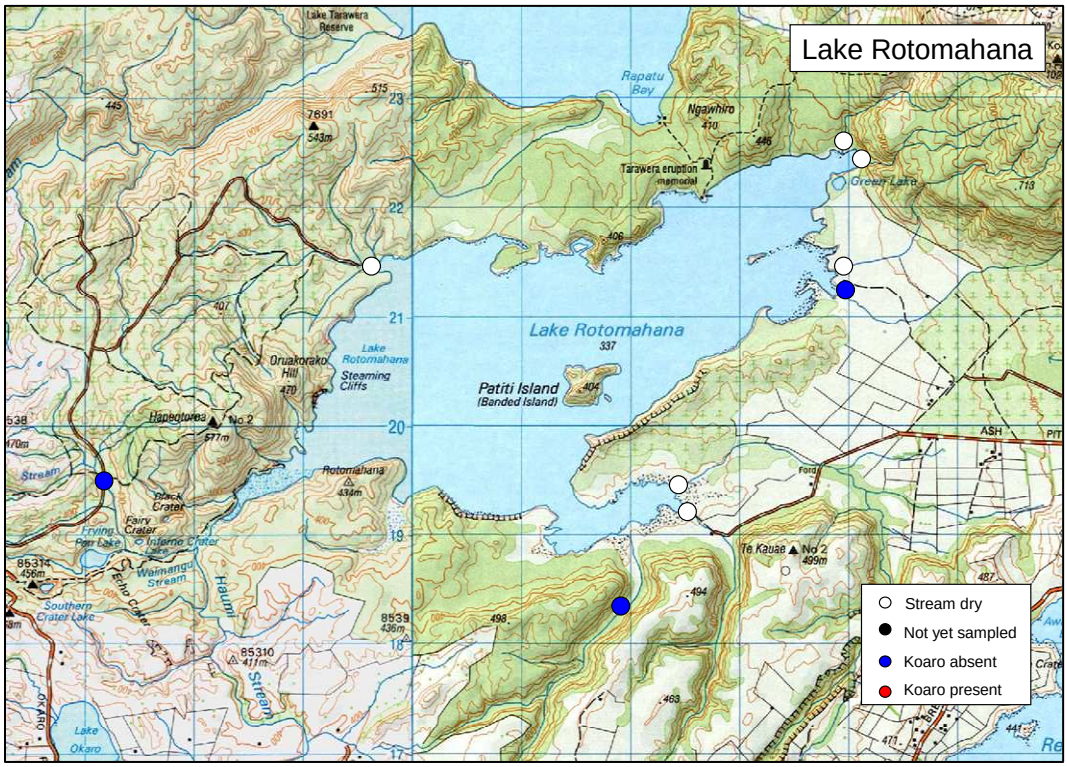

Figure 14: Presence or absence of koaro in the inlet streams of Lake Rotomahana and the location of streams still to be checked.

3.12 Lake Rerewhakaaitu

Maori fisheries for koaro were historically reported in this lake but no koaro were found in the two main tributary streams during the 2007 and 2008 surveys (Fig. 15). These are now dominated by trout. One tributary stream is yet to be checked but is unlikely to contain koaro because of a lack of suitable habitat.

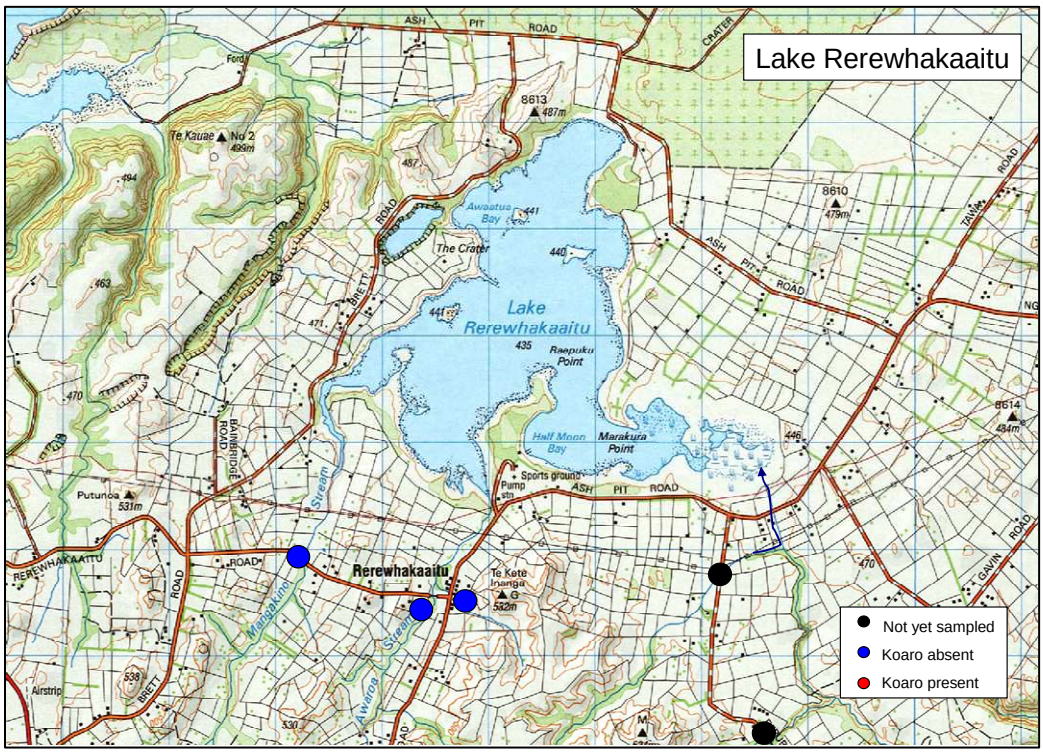

Figure 15: Presence or absence of koaro in the inlet streams of Lake Rerewhakaaitu and the location of streams still to be checked.

3.13 Lakes Okaro and Ngahewa

Lake Okaro has an outlet stream that drains into Lake Rotomahana and as koaro were present in Rotomahana, they will have also colonised Okaro by the upstream migration of juveniles. Alternatively, koaro may have been stocked into Okaro. One site in the main inlet stream flowing into Lake Okaro has been checked (Fig. 16), but land use in this catchment has affected koaro stream habitat and this stream therefore needs to be checked further upstream, where habitat is better (i.e., riparian cover occurs), to provide a definitive test for the presence or absence of koaro. The single tributary stream flowing into Lake Ngahewa is relatively large (Fig. 17) and rainbow trout were the only fish present. Koaro are now absent in this stream and the lake.

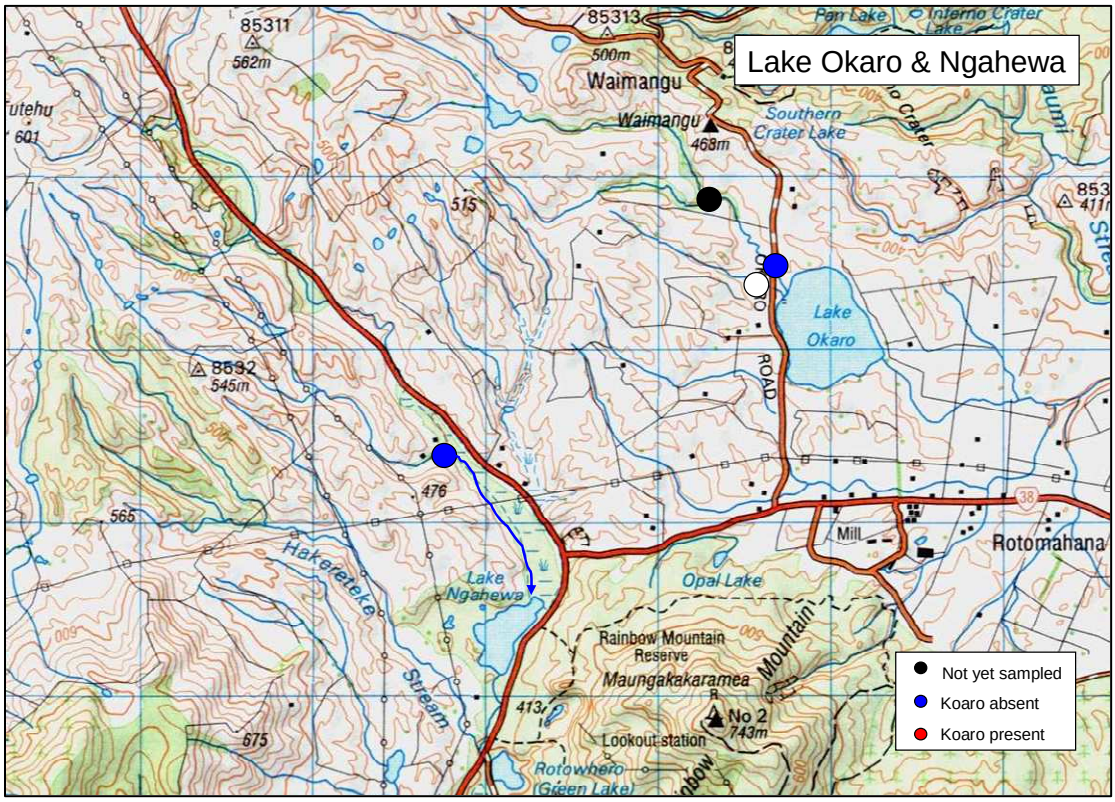

Figure 16: Presence or absence of koaro in the inlet streams of lakes Okaro and Ngahewa and the location of streams still to be checked.

The outlet for Lake Ngahewa drains into the Waiotapu stream which enters the Waikato River at Waimahana. There are no major falls or chutes in the Waiotapu Stream between Waimahana and Lake Ngahewa, so it is probable that koaro once accessed this lake via the upstream migration of juveniles sourced from either the sea (i.e., diadromous fish) or from Lake Taupo (landlocked fish). However, the establishment of trout and later smelt will have lead to the demise of any koaro present. Koaro are no longer present in this lake.

Figure 17: Tributary stream flowing into Lake Ngahewa.

3.14 Lakes Ngapouri and Tutaeinanga

Lake Ngapouri also drains into the Waiotapu Stream and so it too will have once been colonised by koaro. The koaro would have persisted in this lake as a landlocked population, and migrated upstream to colonise Lake Tutaeinanga. The very name of this lake suggests that juvenile galaxiids (i.e., inanga as occurred in the more northern Rotorua lakes) once occurred in it. The stocking of trout and smelt in these lakes will have resulted in the demise of koaro as it is no longer present in either (Fig. 18).

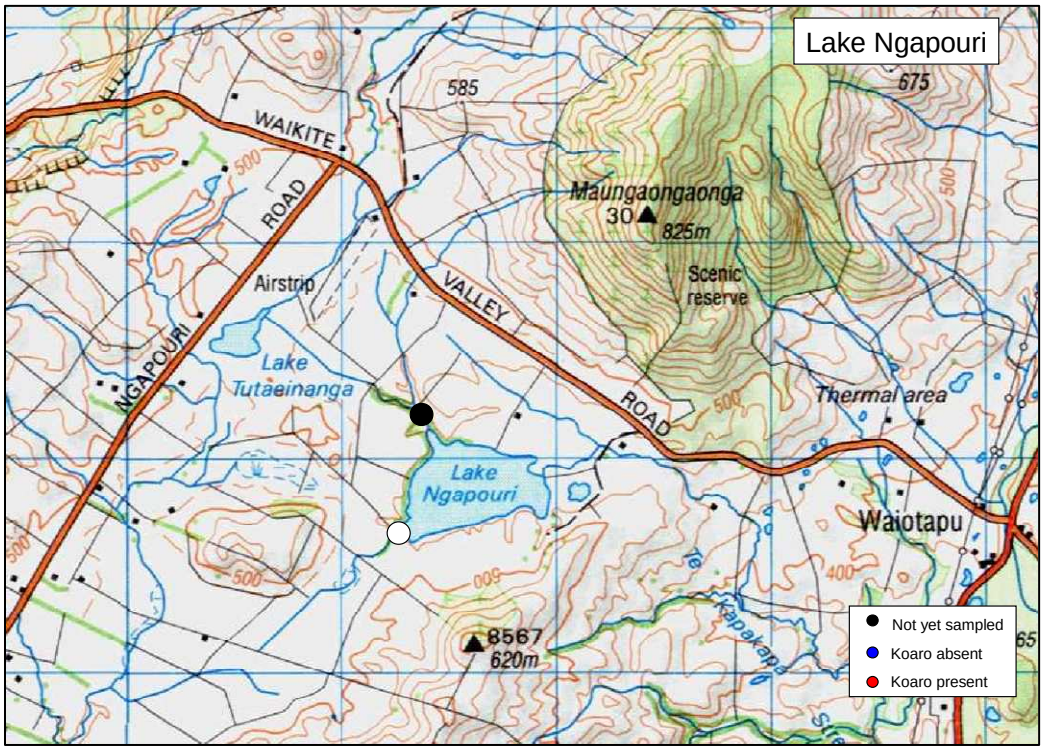

Figure 18: Presence or absence of koaro in the inlet streams of lakes Ngapouri and Tutaeinanga and the location of streams still to be checked.

4. Koaro conservation status

The Te Arawa lakes have now been extensively surveyed to provide an up-to-date database on the distribution of koaro in the tributary streams of these lakes. Although a number of stream sites still remain to be checked, koaro are now present in only 16 of the 40 streams checked (Fig. 19).

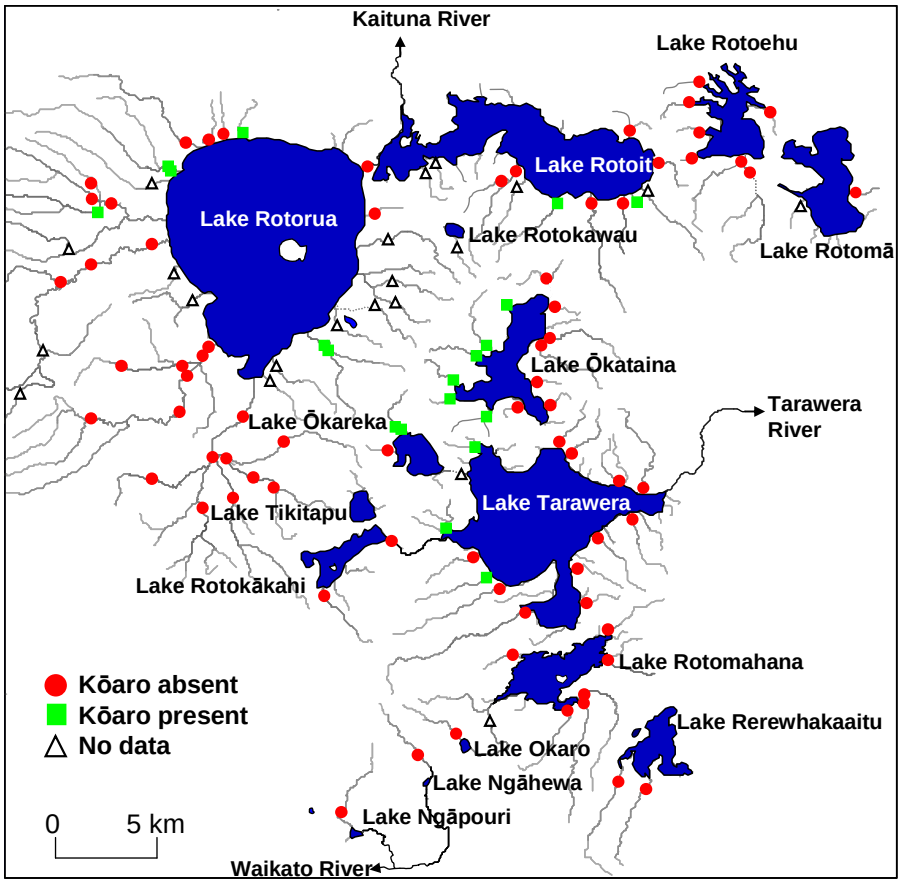

Figure 19: Summary of survey results for koaro in the inlet streams of the Rotorua lakes at July 2008.

The survey results add to the preliminary assessment of the conservation status of koaro provided by Rowe & Kusabs (2007). They confirm that koaro is now extinct in four lakes (Rotoehu, Rotoma, Rerewhakaaitu, Rotokakahi) and probably extinct in another five (Okaro, Rotomahana, Ngahewa, Ngapouri and Tutaeinanga). These later extinctions are qualified as although koaro are very likely to have historically occurred in all these lakes, there is no proof of this at present. The koaro was present in Rotokawau, and is probably extinct there as well, but further checking of the inlet stream for this lake is required to determine this. Although the koaro is not present in

Tikitapu today, it may not have occurred historically in this lake. Similarly, it is not known whether koaro ever occurred in Lake Rotoatua or whether it is present there today.

It is therefore probable that koaro has become extinct in ten of the seventeen lakes, with relict populations (present in three or less streams) in another four lakes (Rotorua, Rotoiti, Okareka, and Tarawera). This species is only secure in Lake Okataina where it is still common in all six streams. Given its decline in other central North Island lakes (e.g., Taupo, Rotoaira, Waikaremoana, Waikareiti, Rotopounmau), and in many large South Island lakes (e.g., Tekapo, Wanaka, Whakatipu), where the highly piscivorous brown trout has decimated stocks to a much greater extent than the rainbow trout (Rowe et al. 2003), the status of lacustrine populations of this species in New Zealand is now precarious and management is required to halt its further decline.

5. Options for koaro protection and restoration

Sixteen stream sites were identified where adult koaro are still present in the Te Arawa lakes. These streams are listed in Table 3 and the potential for protection, enhancement and restoration is scored depending on the relative abundance of the koaro present (i.e., rare, common, abundant) as well as the amount of habitat present (i.e., large, medium, small). The presence of culverts that can be used to create barriers to trout and of riparian vegetation that helps create habitat for koaro is noted.

Table 3: Stream sites where koaro protection, enhancement or restoration is possible.

Lake	Streams where koaro are present	Size of habitat	Status of koaro	Score (1-5)	Culvert present	Riparian cover
Rotorua	-Komutumutu Stream	Large	Rare	4	Yes	Maintain
	-Hamurana Stream	Medium	Rare	3	Yes	Improve
	-Waingaehe Stream	Large	Common	4	Yes	Improve
	-Taniwha Springs Stream	Small	Rare	2	Yes	Maintain
Rotoiti	-Ruato Stream	Medium	Abundant	5	Yes	Maintain
	-Waiiti Stream	Small	Common	3	Yes	Maintain
Okareka	-Boyes Beach Stream	Medium	Common	4	Yes	Improve
Okataina	-Log Pool Stream	Small	Abundant	4	No	Maintain
	-Parimata Bay Stream	Large	Common	5	No	Maintain
	-Kaikakahi Bay Stream	Medium	Common	4	No	Maintain
	-Motuwhetero Inlet Stream	Large	Common	5	No	Maintain
	-Pukahu Stream	Medium	Common	4	No	Maintain
	-Haumingi Bay Stream	Small	Common	3	No	Maintain
Tarawera	-Te Hirau Bay Stream	Large	Common	5	No	Maintain
	-Kotukutuku Bay Stream	Small	Rare	2	Yes	Maintain
	-Otumutu Inlet stream	Small	Rare	2	Yes	Maintain

On-going protection of these streams is required to maintain their koaro populations. In the first instance, this list of sites provides a basis for future listing by Environment Bay of Plenty in Regional Plans so that the streams are flagged in any application for land and water resource consents. This listing process is designed to prevent or mitigate the effects of development at these sites on koaro. For example, changes in the culverts under roads by either the District Council or Transit New Zealand may allow trout better access to such sites and create adverse conditions for koaro. Conversely, such culverts can be altered to reduce trout access and so improve conditions for koaro. Removal of riparian vegetation would also adversely affect koaro, whereas riparian planting or afforestation could help this species. High priority sites requiring protection of existing koaro stocks include the Komutumutu and Waingaehe Streams in Lake

Rotorua, the Ruato Bay Stream in Lake Rotoiti, Boyes Beach Stream in Lake Okareka, the Te Hirau Stream in Lake Tarawera and all inlet streams in Lake Okataina. Protection of the Ruato Bay Steam population in Lake Rotoiti, the Boyes Beach Stream population in Lake Okareka and the Te Hirau Stream population in Lake Tarawera are considered high priorities as the loss of koaro in these streams would most likely lead to the extinction of koaro in their respective lakes.

Protection of these existing koaro populations requires management to maintain the low density of trout by the creation of a barrier to their upstream migration. It also involves the maintenance of riparian cover to protect koaro habitat. The enhancement of koaro requires a more active form of management. Exclusion of trout is feasible where a road crosses over the stream and the culvert provides a potential site to prevent trout access. It is also possible where the flow is mainly from a spring as a barrier can be constructed in the channel to prevent trout access without fear of flood damage or of trout access when floods occur. Trout exclusion barriers are more difficult to create in streams that are prone to flooding and/or where there are no existing sites for the creation of a trout barrier.

The scope for koaro enhancement is high in three Lake Rotorua Steams (Waingaehe, Komutumutu and Waiteti) where the amount of habitat is large and trout exclusion is possible because of road culverts. In particular, enhancement of koaro in the Komutumutu Stream is warranted because of the ideal habitat present for this species here (Fig. 20) and the presence of a rock-hewn culvert under Dalbeth Rd (Fig. 20) that provides opportunities to exclude trout.

The restoration of koaro in locations where they are now extinct may also be feasible by removal of trout and smelt followed by koaro stocking. For example, koaro were not found in the Waiteti Stream in Lake Rotorua above Dalbeth Road. A large amount of good habitat for koaro occurs in this stream (Fig. 21). Although it is used by trout for spawning, it may not be a major spawning tributary and it is possible that exclusion of trout from above Dalbeth Road would have little effect on trout recruitment to Lake Rotorua. If so, then the exclusion of trout would create a large amount of habitat for koaro, and koaro could be stocked into this stream reach to create a new population.

Figure 20: Koaro habitat in Komutumutu Stream above Dalbeth Road (top) and the culvert beneath the road (bottom).

Figure 21: Optimal koaro habitat in the Waiteti Stream, Lake Rotorua above Dalbeth Road.

On a larger scale, trout are no longer present in Lake Rotokawau where koaro were once present. Although the inlet stream may still hold a relict population, koaro are now likely to be extinct in this lake because of the presence of smelt. Restoration would therefore involve the removal of smelt via treatment with a piscicide. This is a deep lake and it would therefore only be possible to eradicate smelt by repeated treatments around the beaches. Lake Ngahewa is also a potential site for a lake-wide restoration programme. Both trout and smelt are present, but the trout fishery here is of little value compared with fisheries in the other Rotorua lakes. Restoration of koaro here would involve the removal of both these species and stocking with lacustrine koaro.

6. Summary

The koaro is an iconic, heritage species that once dominated many large, inland lakes in New Zealand and in the central North Island it is a taonga species for Maori. It once added significant vertebrate biodiversity to the Te Arawa lakes, and this has been drastically reduced in all lakes to the point where this species is probably now extinct in ten lakes, confined to a few inlet streams in another four and only secure in one lake. Its decline will undoubtedly continue unless its current status is safeguarded for future generations. Where possible, the existing stream populations need to be protected and strengthened. In addition, it would be feasible to restore populations in some tributary streams where it is now absent. This is technically feasible without harming the now valued trout fisheries of these lakes because many of the streams that are now dominated by trout are not important for trout spawning and recruitment. Trout access to these streams can be blocked allowing re-colonisation by koaro and the creation of koaro sanctuaries. In addition, it may be possible to restore koaro to some of the smaller lakes (e.g., Rotokawau, Ngahewa) as this would be technically and logistically possible and not affect important trout fisheries. Such restoration requires the identification of suitable sites and the development of site-specific restoration plans, as the impediments to re-colonisation by koaro vary between them. It also requires the prioritisation of such sites based on the chances of success versus likely overall cost as already completed for Lake Rotoaira (Rowe & Konui 2007). Such detailed plans, costings and rankings are beyond the scope of this report, however, a number of sites have now been found that indicate a high potential for restoration success. These are listed and discussed to provide the initial basis for the development of an overall restoration plan.

Although small-scale protection and restoration of koaro can be readily achieved in a number of streams by the exclusion of trout and/or improvement to riparian vegetation, larger scale restoration can be expected to present greater logistical problems and increases in cost. At present, the koaro is not regarded as a rare or threatened species in New Zealand by the Department of Conservation so is not a priority for management by DOC. However, this stance, while valid for diadromous stocks, fails to recognise the significance of lacustrine koaro as a taonga and heritage species and it does not recognise the loss of indigenous biodiversity in inland lakes that has already occurred and will continue to occur if koaro stocks continue to decline. The extinction of such stocks in at least eight of the Te Arawa lakes (this report) and in Lake Rotopounamu (Rowe 1993b), coupled with its decline in other central North Island lakes and South Island alpine lakes (Rowe et al. 2003; Rowe & Konui 2007) adds weight to the need to conserve this species. The Crown commitment to protect indigenous fisheries enshrined in the Treaty of Waitangi reinforces the case for a re-examination of its prioritisation for management by DOC. In the meantime, restoration of these larger sites is not considered viable, although there may be interest by local environmental groups who can access funds from donations and charitable trusts to achieve this.

7. Acknowledgments

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