Biosecurity status of non-native freshwater fish species in Northland

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Executive summary

Seven species of warmwater, introduced freshwater fish currently occur in Northland and can develop self-sustaining populations in lakes. Water temperatures in Northland are more suitable for the proliferation of these fish than in other regions of New Zealand and Northland has an abundance of small lakes that would provide ideal habitat for them. Many of these lakes are currently near pristine and would be adversely affected by the introduction of such fish. In particular, such fish can reduce the potential use and values of lakes by;

- reducing water clarity,
- increasing the rate of eutrophication,
- limiting lake ecosystem services,
- reducing endemic biodiversity, including tāonga and mahinga kai species,
- allowing the proliferation of new diseases and parasites, and
- reducing options for lake restoration thereby creating an inter-generational legacy cost.

The development of a business case to control the spread of the introduced warm-water fish in Northland is therefore urgently needed because of the acute vulnerability of the region's existing lakes and waters to these species. The future proliferation of water storage dams and ponds for irrigation will also require the development of a plan to ensure that such artificial environments remain fit for purpose.

The most widespread and abundant species present in Northland is gambusia. It was introduced as a possible control agent for mosquito larvae but its ability to achieve such control is no greater than for other small fish species that do not cause problems. It is now well established in Northland so cannot be eradicated, but its future spread to the many near-pristine dune lakes in the far north needs to be vigorously resisted as it would degrade these environments. It is having a major impact on threatened species of galaxiid fish in the Kai Iwi lakes and the development of lake-specific control measures is required there. Goldfish are also now widespread in Northland and cannot be practically eradicated. A policy of containment is therefore appropriate because this species can combine with other warm-water fish species to degrade lake water quality. Catfish are now common throughout the Wairoa River catchment but appear to be scarce elsewhere and have gone from Lake Omapere. Containment within the Wairoa River catchment is therefore required. Rudd are present in a number of the larger lakes and in several streams in Northland so eradication is now not feasible for this species. However, its impact is lower than that of gambusia and catfish and so a policy of containment rather than eradication is therefore advisable.

The remaining species have more restricted distributions and eradication is both feasible and desirable. A number of isolated populations of koi carp occur mainly in small lakes and ponds. Given the scarcity and small size of these waters, its eradication from most of Northland may be achievable and some populations have already been successfully eradicated. Tench are also present in Northland but they have been recorded in very few locations. The isolated nature of these indicates that eradication may be practical in Northland. However, the ecological impact of tench is low relative to the other species so containment is also an option. The least common species present in Northland is perch. It is currently known from only two locations, but its potential impact on Northland lakes is far greater than for all other species. It therefore poses a major threat to all Northland lakes and a policy of eradication is required to prevent its future spread north of Auckland.

Given the main vectors responsible for the spread of these introduced fish species in Northland, targeted public education will be an essential component of any business case. A rapid detection and response capability is also required to underpin containment and to detect any future introductions of these species, or any new ones that may enter New Zealand either accidentally or illegally.

1 Introduction

Northland Regional Council wishes to address the potential threats to the region's water quality and freshwater environments posed by introduced species of freshwater fish. In particular, information is required to support the development of a business case for the region, but with immediate reference to the Kai Iwi Lakes on the west coast, north of Dargaville.

To assist in this process information is required on the exotic (i.e., introduced, non-native) fish species present in Northland, their effects, and the patterns and trends in geographic distribution in the region relative to those occurring nationally. Advice is also required on the agents responsible for the spread of these species and on future and emerging threats.

Introduced freshwater fish in New Zealand can be divided into warm- and cold-water species and both are present in Northland. Brown and rainbow trout (*Salmo trutta* and *Oncorhynchus mykiss* respectively) are cold-water species and are less common in Northland than in other regions because of the generally warmer waters and the relatively high frequency of large flood events which displace these fish downriver (Smith et al. 2007). The effect of these cold-water species on endemic biodiversity in New Zealand has been relatively well documented (McDowall 2003; 2006). The salmonids are known to have reduced the biodiversity of native fish and significantly reduced galaxiid fish, especially in large inland lakes. But these impacts on native fish are largely confined to the large, cooler, inland lakes where the salmonids thrive. Trout do not generally occur in the smaller, coastal dune lakes of New Zealand because these environments usually lack the spawning streams required for self-sustaining trout populations to develop. Trout only occur in such lakes where populations are maintained by the annual stocking of hatchery-reared trout. The lowland, coastal lakes of New Zealand, including most of those in Northland, have therefore been largely spared from the biodiversity impacts of trout and they are not physically degraded by these fish as they do not affect water quality.

In sharp contrast to trout, the warm-water fish species present in New Zealand, such as koi carp, catfish, perch, gambusia, goldfish, tench and rudd can readily develop self-sustaining populations in lakes lacking inlet streams and are known to contribute to the degradation of water quality caused by increased nutrient loadings. Water temperatures in Northland are more suitable for the proliferation of these fish than in the other regions of New Zealand and Northland has an abundance of small near-pristine lakes which would provide ideal habitat for them. The development of a biosecurity strategy to control introduced warm-water fish species in Northland is therefore a high priority because of the acute vulnerability of the region's lakes to these species. Any further degradation of the region's lakes caused by the spread of these exotic fish species needs to be vigorously resisted though a sustained programme of biosecurity actions. This report is designed to provide the information and data required to support the development of a business case for protecting Northland's freshwater resources, especially its lakes.

2 Effects of introduced fish on water quality and biodiversity

Rainbow and brown trout were introduced to New Zealand by early settlers and have produced valued fisheries but have also greatly reduced galaxiids in many large New Zealand lakes (McDowall 2003, 2006). In rivers where trout now dominate the fauna, they have reduced native fish biodiversity by 33% (Rowe 2013, Figure 2-1). Whereas the introduced salmonids are not known to reduce water quality in New Zealand lakes or rivers, they have therefore had a significant negative impact on native biodiversity.

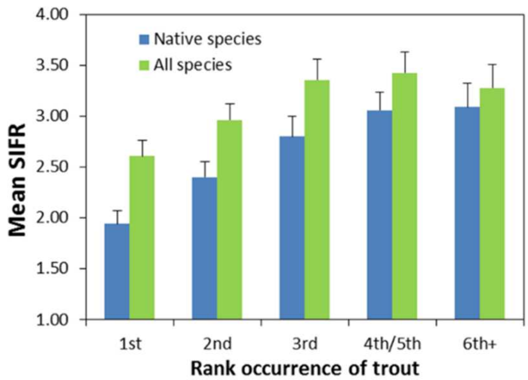

Figure 2-1: Effects of trout on native fish diversity in New Zealand rivers from Rowe (2013). (SIFR is an index of fish diversity at a river catchment scale, and the rank occurrence of trout indicates the extent to which trout dominate the fish fauna).

In contrast, the warm-water introduced fish species present in New Zealand such as koi carp (*Cyprinus carpio*), perch (*Perca fluviatilis*), catfish (*Ameiurus nebulous*), rudd (*Scardinius erythrophthalmus*), goldfish (*Carassius auratus*), gambusia (*Gambusia affinis*) and tench (*Tinca tinca*) are known to collectively contribute to the deterioration of water quality in New Zealand lakes, reservoirs and ponds (Rowe 2007; Schallenburg & Sorell 2009; Rowe & Wilding 2012). Some of these species are also responsible for drastic drops in endemic biodiversity.

Hanchet (1990) reviewed the effects of koi carp and concluded that at high densities they could increase turbidity and reduce water clarity in some New Zealand lakes. Similarly, Rowe et al. (2008) reviewed the effects of gambusia and perch in Australasian waters and found that both these species can reduce endemic biodiversity and contribute to the development of algal blooms in lakes. High densities of goldfish have caused increased turbidity in Canadian ponds (Richardson et al.1995) and have been implicated in the development of toxic algal blooms in the Vasse River, Western Australia (Morgan & Beatty 2007). The remaining species present in New Zealand (tench, catfish, and rudd) have not been directly associated with a decline in water quality, but Rowe (2007) showed that the water clarity in small North Island, New Zealand lakes declined as the number of the warm-water fish species increased (Figure 2-2). It was concluded that these species indirectly reduce water clarity by increasing siltation from sediment disturbance, reducing macrophyte cover, increasing nutrient recycling and by reducing large zooplankton.

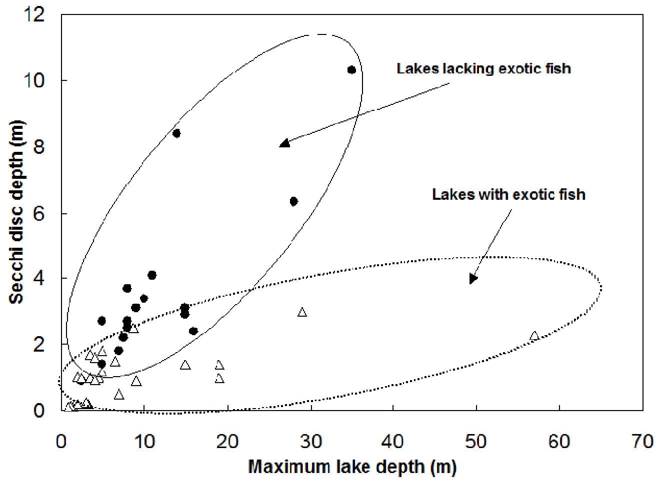

Figure 2-2: Effects of introduced warm-water fish on the clarity of small New Zealand lakes.

The individual effects of each species on lake ecosystems combine via positive feedback loops to accelerate the process of eutrophication caused by excess nutrients. This process results in reduced water clarity with flow-on effects to macrophytes and hypolimnetic oxygen levels (Figure 2-3). It follows, that lakes containing high densities and/or multiple species of these introduced fish are more vulnerable to a deterioration in water quality than lakes lacking them. The corollary to this is that lakes with poor water quality are at greater risk of further deterioration should one or more of these species be introduced to them.

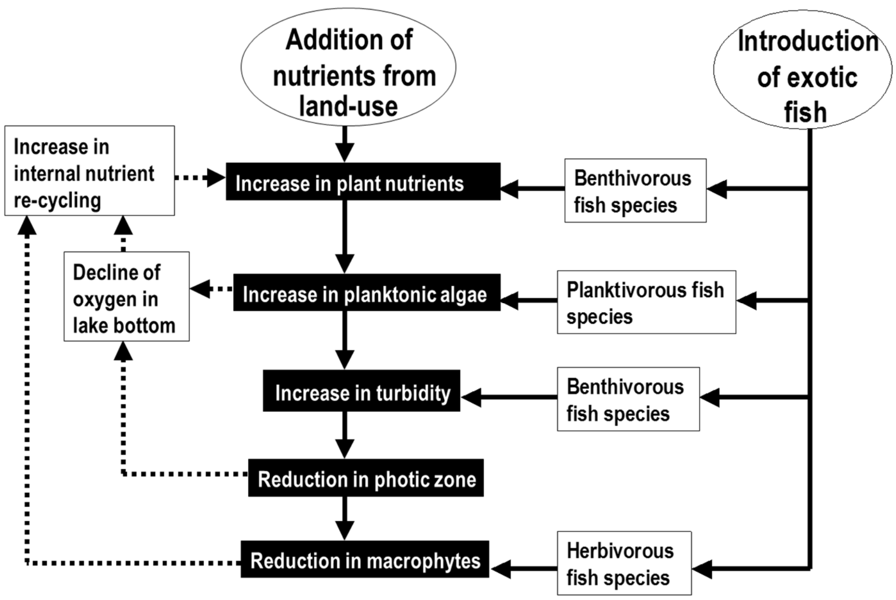

Figure 2-3: Model for the effects of introduced warm-water fish on lake eutrophication and water clarity in New Zealand.

A number of indices have now been developed to predict the overall risk of environmental impacts from introduced freshwater fish in Australia, the USA and UK (e.g., Bomford & Glover 2004; Kolar 2004; Copp et al. 2005; Hammond 2009). Rowe & Wilding (2012) developed a similar risk index based on these models but customised to New Zealand's aquatic ecosystems and climate conditions and applied this to the species now present. They found that perch, koi carp, gambusia, brown trout, silver carp, catfish, orfe and rainbow trout, all had a high risk of impact, whereas the risk for rudd, salmon, goldfish and tench was moderate. When the risk of ecological impact was compared with the risk of establishment (i.e., from propagule pressure, breeding rate and ease of spread), the species of most concern in New Zealand were perch, koi carp, gambusia and catfish in that order (Figure 2-4). Whereas koi carp, gambusia and catfish are now widely known as pest fish species in New Zealand, the significant negative impact of perch on New Zealand lakes and reservoirs is not generally appreciated as yet.

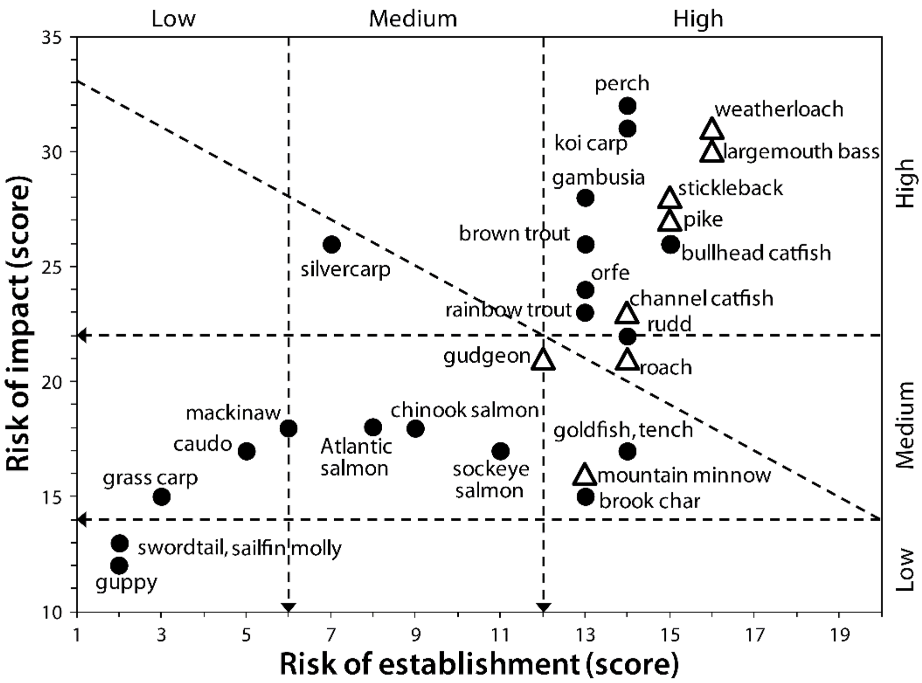

Figure 2-4: Risk of ecological impact versus establishment for introduced freswater fish in New Zealand waters.

Several case studies illustrate the environmental risk posed by perch in New Zealand lakes. Closs et al. (2001) documented the negative impact of perch on common bullies (*Gobiomorphus cotidianus*) in several small South Island lakes. Similarly, in Lakes Wainamu, Wiritoa and Ototoa in the North Island, the mean catch rate of bullies is much lower in lakes containing perch than in lakes lacking them (author's unpub. data). In the North Island, perch were illegally introduced to Lake Ototoa (South Kaipara Head) around 2000. Before this, dwarf inanga (*Galaxias gracilis*) were abundant in this lake. However, between 2003 and 2011 and following the development of a large perch population, dwarf inanga declined by over 99% such that this threatened species is now on the brink of extinction here (Table 2-1). Perch also reduced crayfish/koura abundance in this lake by over 90% and common bullies by over 80% (Table 2-1).

Table 2-1: Total numbers of native fish caught in Lake Ototoa (Auckland) before and after perch became abundant using two methods. (The same number of traps and locations were used on each occassion).

Species	Common name	Total catch (No.)			
		Minnow trap 2003	Minnow trap 2011	Fyke net 2003	Fyke net 2011
Galaxias gracilis	Dwarf inanga	455	2	332	1
Gobiomorphus cotidianus	Common bully	919	333	1363	28
Paranephrops planifrons	Crayfish/koura	12	2	133	11

Whereas trout have reduced endemic biodiversity in the colder, high altitude inland lakes of New Zealand, perch are the main threat to endemic biodiversity in the lowland, coastal lakes of New Zealand. They have had very similar ecological effects on native fish and crustacea in Australian waters (Rowe et al. 2008).

Perch have also been associated with cyanophyean blooms in a number of New Zealand lakes and reservoirs (e.g., Smith & Lester 2006; Rowe et al. 2008), hence they are likely to have contributed to the deterioration of water quality in many of the small lakes on the west coast of the North Island from Taranaki down to Wellington. This is because there are no natural piscivorous predators (e.g., pike) in New Zealand to provide a check on their population size. As a consequence, large populations of small, stunted fish develop. The resultant strong predation on zooplankton allows algal blooms to develop and water clarity is consequently reduced. In some lakes, toxic algal blooms are facilitated by perch predation on zooplankton. For example, perch have been identified as a major factor in the development of toxic algal blooms in the Karori Reservoir, Wellington (Smith & Lester 2006). This role is emphasized by observations in other New Zealand lakes. A dense population of small perch (and no other fish) was found in Lake Tauanui (Northland) when it was sampled by NIWA in 1992. This lake has no inlet or outlet and occurs in a volcanic cone so has a very small catchment fed primarily by rainwater. Consequently, its water quality was expected to be relatively high. Surprisingly, it was highly eutrophic and in 1992 supported a dense cyanophycean bloom. Action by the Auckland Regional Council to reduce perch in Lake Wainamu by netting resulted in improved water clarity, and perch removal has been recently undertaken in the Karori Reservoir (part of Zealandia) to reduce the risk of algal bloom formation there. These observations and actions reflect the increasing realisation by Regional Councils that perch can be a major factor contributing to the deterioration of water quality in New Zealand lakes and reservoirs. Their ability to significantly reduce both endemic biodiversity and water quality is why they pose the main threat to small, coastal lakes in northern New Zealand.

Gambusia are now present in many Northland waters and can also have a major impact on endemic biodiversity, and this will be particularly so in Northland. This species has been implicated in the decline of the dune lakes galaxias in Lakes Taharoa and Waikere and in the extinction of this species in Lake Kai Iwi (Rowe 2003). Gambusia are also known to affect mudfish in permanent wetlands (Barrier & Hicks 1994; Ling & Willis 2005) and inanga in shallow, still- water environments such as lakes and wetlands (Rowe et al. 2007), many of which occur in Northland.

Managers of aquatic resources need to weigh the negative environmental impacts of introduced pest fish against their potential benefits. Perch are viewed as a a useful sports fish by some anglers, especially in waters where trout cannot survive. This could apply to a number of Northland lakes, but the risk of negative impacts by perch is very high and, given the widespread access to good marine fishing in Northland, perch fisheries are unlikley to appeal greatly to locals or tourists. Hence, the economic benefit of perch fisheries in Northland would be low whereas the environmental costs would be high. As a consequence, their use for fishery purposes could not be sensibly supported in Northland, unless sterile, non-breeding stocks can be produced and selectively used for this purpose.

In the case of gambusia the net benefits are also very doubtful. Gambusia are still commonly perceived as a useful control agent for mosquito larvae but there is no evidence to support this and, in Australia, their role in controlling mosquito larvae is no greater than that of other small, native fish species (Hass et al. 2003; Hurst et al. 2006). Given their negative inpact on endemic biodiversity, which includes amphibia and Odonata (dragonflys) as well as native fish (Rowe et al. 2008), their use in mosquito control cannot be supported.

3 Current status of introduced fish in Northland

A search of the New Zealand Freshwater Fish Database (NZFFD) retrieved all records of introduced fish in Northland up to December 2013. Ten species are known to occur in the region (Figure 3-1, Table 3-1) with gambusia being by far the most widespread (present in 165 of 289 sites surveyed). Koi carp were recorded in 11 of the 289 sites surveyed, with catfish in 10 and perch in only 1.

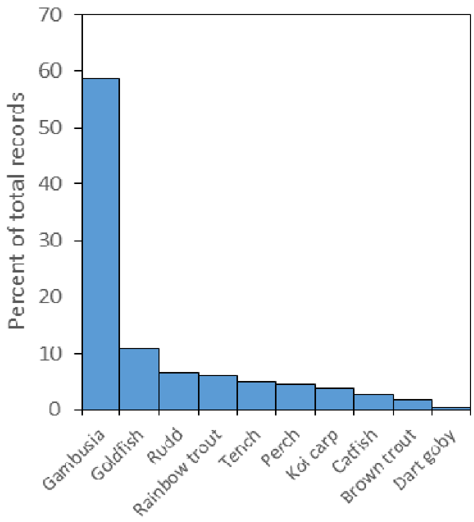

Figure 3-1: The relative occurrence of introduced freshwater fish species in Northland.

When this pattern of relative occurrence is compared with that for New Zealand as a whole (Table 3-1), it is apparent that gambusia are much more prevalent in Northland than in the rest of New Zealand.

Table 3-1: Relative occurrence of introduced fish species in Northland as against New Zealand.

Species	Relative occurrence (%)		Over/under represented in Northland
	Northland	New Zealand	
Gambusia	57	7	Over
Goldfish	13	5	Over
Rainbow trout	10	16	Under
Rudd	6	2	Over
Koi carp	4	1	Over
Brown trout	3	57	Under
Catfish	3	2	Over
Tench	2	1	Over
Perch	0.5	3	Under
Dart goby	1	0.1	Over

Goldfish, rudd, koi carp, catfish, tench and dart goby are also over represented in Northland but the dart goby is only found in Northland so its over-representation here is not unexpected. Rainbow trout, brown trout and perch are all under-represented in Northland at present. This is not surprising given that the warmer Northland waters are generally unsuitable for trout. Perch could thrive in Northland waters hence their current scarcity here is not because the conditions are unsuitable but because they have not been widely stocked in this region for sports fishery purposes.

The frequency distribution for the accumulation of records of introduced fish in Northland over time (Figure 3-2A) shows a steady increase in records of warm water fish species from 1978 to 1998, followed by a rapid increase between 1999 and 2003. This rapid increase probably represents the greater emphasis on surveying and reporting at this time rather than a more rapid spread of these introduced fish. Since 2003, the rate of increase in new records has slowed also reflecting the reduced intensity of survey work over this period.

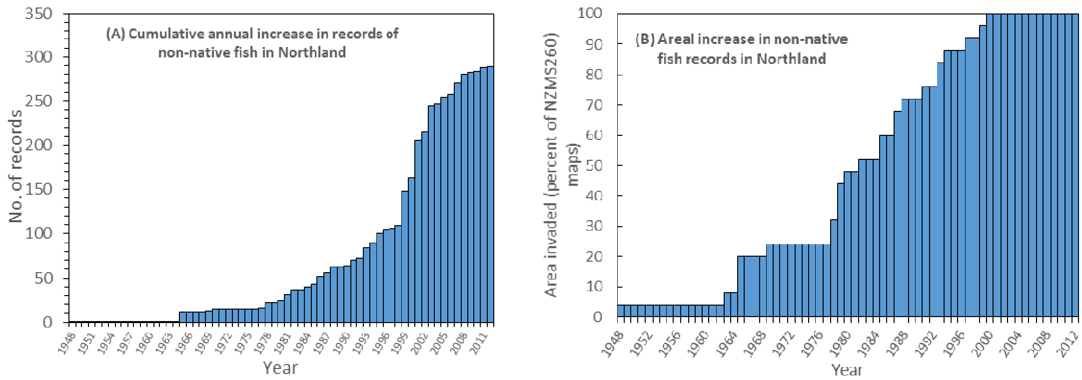

Figure 3-2: Cumulative increase in (a) records of introduced fish and (b) NZNS260 maps where introduced fish occur in Northland.

Similarly, the occurrence of one or more of the introduced species in each of the 26 NZMS260 maps covering Northland was less than 10% until 1964 and increased rapidly after 1976 reaching 100% by 2000 (Figure 3-2B). Hence the overall pattern of geographical spread follows the pattern of increase in records over time.

A better indication of the spread of introduced fish over time in Northland can be gained from an analysis of species geographical distributions as shown in Figure 3-3. It should be noted that these maps show the reported locations for each introduced fish species to date, hence they do not indicate places where these species may now occur but which have not yet been sampled.

Gambusia is now widespread throughout the region (Figure 3-3A) and is still being spread with DOC surveys finding it in Lake Rototuna (North Kaipara Head) in 2001. It was not present there in the 1990s. Goldfish are also widely distributed in Northland (Fig 3-3B).

In contrast, all the other species have comparatively restricted geographical distributions. Therefore, there is some scope to prevent their future spread, especially to lakes and ponds where they do not occur at present and where, if high densities developed, they would degrade both water quality and biodiversity resulting in a decline in ecosystem services. Whereas total eradication may not be possible for all these species, a policy of containment could still be viable. These management options are considered on a species-by-species basis below.

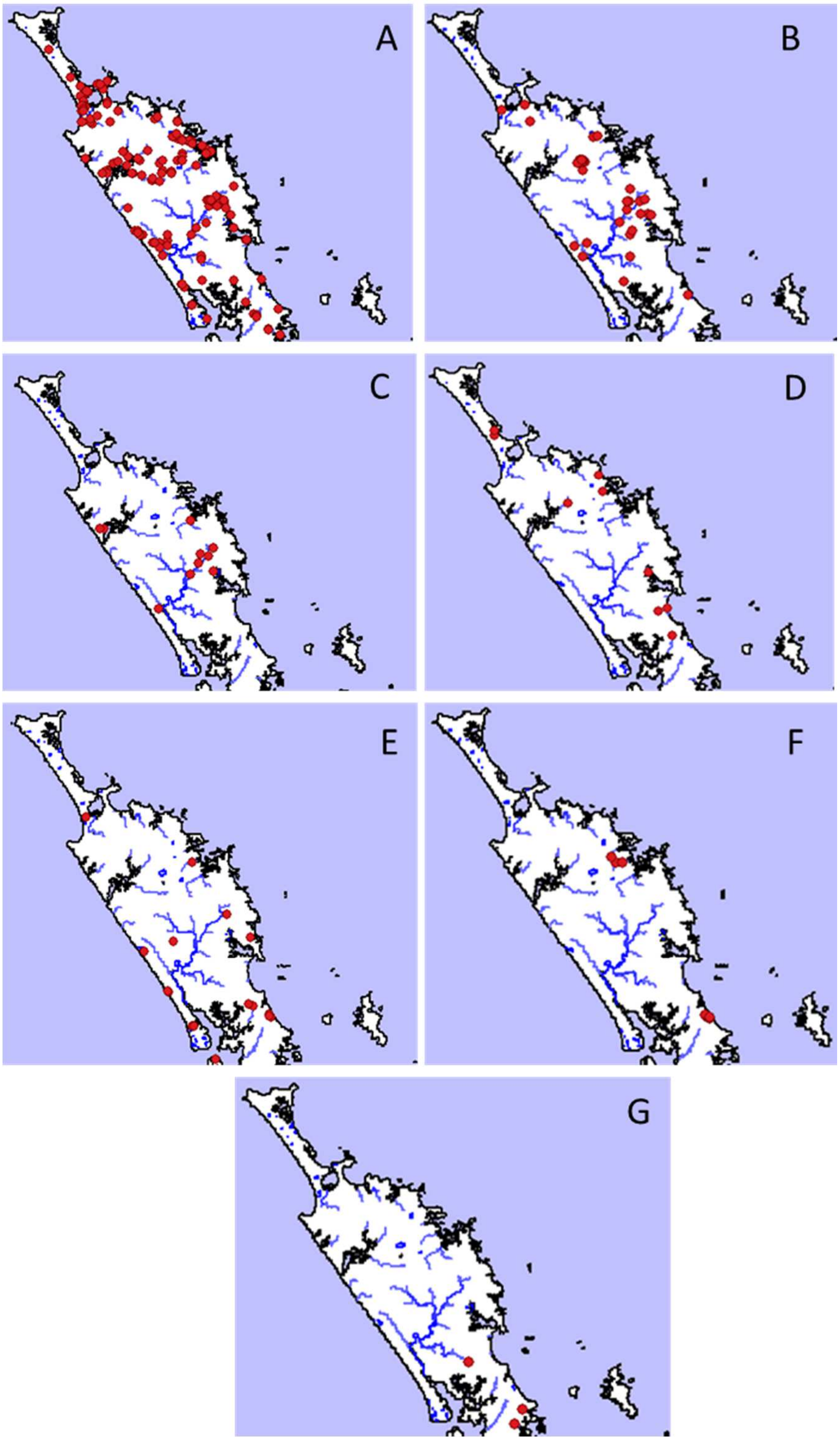

Figure 3-3: Distributions of records for the warm-water introduced fish species present in Northland. (A) gambusia, (B) goldfish, (C) catfish, (D) koi carp, (E) rudd, (F) tench, (G) perch (the red circles indicate where a species has been found).

Catfish are now well established in the Wairoa River catchment (Figure 3-3C) but they appear to be relatively scarce elsewhere in Northland. Isolated populations have been found in a small stream draining into the Hokianga Harbour, in a tributary of the Kawakawa River, and in Lake Ora near Whangarei. Catfish were also historically reported from Lake Omapere, but more recent and comprehensive eel surveys have found none there (Williams et al. 2009). Catfish could be readily spread from the Wairoa River catchment by commercial eel fishermen to a range of other eel fishing waters (including lakes) in Northland. MPI protocols require commercial eelers to wash nets in a saline solution to prevent the transfer of introduced fish and plants. Ongoing education to ensure that new entrants to the fishery are aware of these MPI protocols would be helpful.

Koi carp are present mainly in isolated ponds/lakes in Northland (Figure 3-3D). Riverine populations have only been recorded to date in the NZFFD in Whakanekeneke River (Hokianga Harbour) and in a small stream on the northern fringe of Whangarei. A number of populations (not shown above because there is no record in the NZFFD) have been found in farm ponds and eradicated by the Northland Regional Council and DOC. Koi carp in Lake Parawanui appear to have died out, probably because the original and illicit stocking did not contain both sexes. The number of populations of koi carp in Northland is therefore declining and hence an eradication policy for the remaining koi carp in ponds and lakes is appropriate and will reduce the risk of further spread to other ponds and lakes.

Rudd are also restricted mainly to lakes and ponds in Northland (Figure 3-3E). The current NZFFD records indicate that rudd are present in Lakes Rototuna, Ngatu, Parawanui, Kapoai and Kai Iwi, along with four unnamed lakes/ponds. Comprehensive sampling in the 1990s did not find any in Lake Kai Iwi and it is likely that they have died out there. Populations in other Northland lakes and ponds could, in theory, be eradicated (as with koi carp), but this would be a relatively expensive exercise requiring the use of a piscicide. Furthermore, populations have been recorded in the Waitangi River and a small tributary of the Wairoa River, which are not amenable to eradication. Hence, rudd are likely to stay in Northland and a policy of containment is more appropriate.

Tench are sparsely distributed in Northland at present (Figure 3-3F). This species is recorded only in the Waitangi River because the southern-most population in Figure 3-3 is in Lake Tomarata, which is in the Auckland region. The records of tench in the Waitangi River indicate that the source populations are probably a couple of small and unnamed lakes/ponds in the headwaters and these may also hold rudd. Tench live and breed in the still waters of lakes and ponds rather than in the flowing waters of rivers. Eradication of these few lake/pond populations could therefore reduce tench in the river and may thereby achieve eradication of this species in Northland. This possibility is worthy of future investigation, and coordination with Auckland Council to help ensure this species remains rare north of Auckland would also be useful.

Perch in Northland are only recorded from one site (Figure 3-3G), the Kaikowhiti Stream. Although perch can breed in riverine environments, like tench they prefer lacustrine waters and so the source population of the perch in this stream is probably the small pond just north of the intersection of Golden Stairs Road and Swamp Road, on the entrance road to the quarry. It drains into a small tributary of the Kaikowhiti Stream. Another population of perch in Northland (not recorded in the NZFFD) is Lake Tauanui. The spread of perch in Northland beyond these two locations is to be avoided as far as possible as this species has the potential to create major problems in lakes through its effects on water quality and endemic biodiversity. A policy of eradication is required and is likely to be feasible in Northland.

McDowall (2000) reported the presence of the aquarium species caudo (*Phalloceras caudimaculatus*) in Northland, but the existence of a breeding population in the wild has not been verified to date. When introduced into streams near Perth and Sydney, this species developed breeding populations that displaced gambusia (Corfield et al. 2008). Its invasive potential in Australasian waters, including New Zealand, is therefore likely to be high. Its current status in Northland is unknown and this needs to be determined.

The dart goby was accidentally introduced via freshwater from ship's ballast discharged at sea before the ship(s) enter port. It is now present in at least one stream in Tom Bowling Bay, Northland and in a stream on the east coast of Great Barrier Island (McDowall 2000). Although it is likely to be confined to the lower reaches of these streams, its impact on endemic biodiversity is unknown. The dart goby can be expected to be readily spread to adjacent streams by displacement during flood events and subsequent movement north and south via coastal currents. Its future spread is therefore likely unless it too is eradicated.

Whereas the above introduced fish species provide varying degrees of risk to Northland waters, the introduced fish parasite (*Ligula intestinalis*) also requires some mention. This white tapeworm is common in many European fish, particularly cyprinids, and it is known for its large size (up to 20 cm long by 10 mm wide). As a consequence its presence results in the gross distension of the abdomen of its host species. It can readily transfer to different species of fish and has now been found in several west coast Northland lakes where it infests common bullies. The effects of this parasite on the common bully populations are unknown, but as the bully is the main prey species for many other fish (including eels) the impact of Ligula on native fish may well be significant. Any increase in the distribution of cyprinids (koi carp, goldfish, tench and rudd) in Northland, will facilitate its spread throughout Northland and increase its impact on native fish species because cyprinids are the prime host for this parasite.

4 Vectors and future spread

The primary vectors for the spread of gambusia in Northland are likely to be commercial eel fishermen (for whom gambusia can be a by-catch) and by deliberate (albeit misguided) stocking of ponds by property owners in the belief that gambusia will reduce mosquito larvae there. However, other primary vectors are possible. For example, aquatic birds (shags, swans, ducks, geese, gulls) may also be responsible for the spread of gambusia. Although there is no evidence for this at present, the possibility has not been properly investigated to date.

Secondary vectors are responsible for dispersal from the initial site of establishment within a catchment. Flood events result in escapement downstream and successive colonisation of suitable waters down the catchment. Gambusia can also tolerate high levels of salinity and can be carried by seawater currents along coastlines. Transfer from the Kaituna River to the Tarawera River estuary in the Bay of Plenty is likely to have occurred this way (Mitchell 1985). Similarly, spread to streams entering the Whangarei Harbour is thought to have been facilitated by the tidal movement of seawater around the Harbour. Gambusia then penetrate up the coastal streams/rivers as far as their limited swimming ability allows (i.e., the first chute, fall, perched culvert or weir).

Commercial eel fishers could, in addition to spreading gambusia, also accidently transfer juvenile or larval goldfish, rudd, tench, koi carp catfish and perch to new waterbodies. The MPI protocols for net sanitation are designed to prevent this, but there are no data on the extent to which these protocols are adhered to especially as they are onerous and laborious. Bilge water in boats is also likely to contain juvenile and larval fish that escape from eel nets. Drainage of bilge water from boats is also desirable along with trailer washing to remove weed but such sanitation is not routinely carried out. A programme of targeted public education (and signage) is required to bolster voluntary compliance with such protocols and to align the sanitation of boats and water equipment to prevent the spread of fish along with weed and other pest species. The public relations policy adopted to prevent the spread of didymo within New Zealand provides a useful example of how this can be readily achieved when the public becomes concerned and MPI becomes involved. The potential ecological impact of introduced fish species in Northland lakes would far exceed the impact of didymo and the public have a right to know this risk and a responsibility to help prevent it.

The primary vector for the spread of rudd, koi carp, tench and perch is misguided sports and coarse fish anglers who wish to establish new freshwater fisheries. Good public education coupled with a strong deterrent is needed to prevent this. Perch (along with tench) are designated as an acclimatised sports fish and so come under the management aegis of the Northland Fish & Game Council (NFFG). This Council needs to be clear that should one of these species occur in a Northland lake or pond (other than those already approved by the NFGC) then the Council will make it illegal to fish for these species in that waterbody. This would align with the NRC designation of perch as a pest species in Northland. Whereas such a policy will reduce the incentive to stock new lakes, ponds and dams, the Council has little effective control over such fish in private ponds and dams without the cooperation of the land owner. Public education is therefore an essential component of a control strategy for these species.

The other main vector for the spread of introduced fish in New Zealand is the freshwater aquarium trade and the resultant misguided liberation of live fish into natural waterways when they can no longer be cared for. There is also an increasing global trend for the release of live aquarium fish into the wild as part of Buddhist religious ceremonies (.i.e., ‘mercy release to gain karma’). Again, targeted public education is required to provide viable alternatives and prevent inappropriate releases.

Other major vectors for the spread of pest fish in other countries include anglers who use small live fish as baits and the freshwater aquaculture industry. At present the use of live bait for freshwater angling is not permitted in New Zealand and the importation of new fish species for aquaculture is well controlled. MPI also requires strict attention to biosecurity when approving the transfer of live fish for weed control or aquaculture purposes. Where inappropriate species have been introduced to New Zealand for aquaculture purposes (e.g., marron, channel catfish), the risks were soon identified and the stocks eradicated. The legislation governing the introduction of a new fish species to New Zealand is now much more effective and comprehensive and requires the preparation of an adequate assessment of environmental effects (AEE) and approval from ERMA.

Several species of freshwater fish, notably the dart goby (*Parioglossus marginalis*) and the Asian or streaked goby (*Acentrogobius pflaumii*) have been accidently introduced into New Zealand coastal streams by shipping. Similarly, the streaked and yellowfin goby (*Acanthogobius flavimanus*) have also been spread to coastal waters and river mouths in south eastern Australia by shipping (Rowe et al. 2008). These goby species are present in ballast water taken on in foreign ports and then released at sea before entry to a New Zealand or Australian port. These species all have well developed osmoregulatory abilities that allow them to colonise a wide range of fresh and saltwater habitats. They move from the sea to the coast and to the nearest source of fresh or brackish water. Whereas the streaked and yellowfin gobies are found primarily in coastal habitats they can also colonise fresh and brackish waters near river mouths. In comparison, the dart goby is found mainly in freshwater and brackish habitats. Secondary dispersal of these species then presumably occurs as a consequence of coastal currents, or when the rivers/streams flood and these fish are washed out to sea where they are carried along the coastline by currents.

5 Future & emerging threats

Rowe & Wilding (2012) applied the NZ Fish Risk Assessment Model (FRAM) to fish species which may be introduced to New Zealand in the future. More illegal introductions to New Zealand can be expected because the rate of importation of new species has shown no decline over the past century and has not decreased since legislation was enacted in the 1960s to prevent inappropriate new fish species from being imported and establishing wild populations (Figure 5-1).

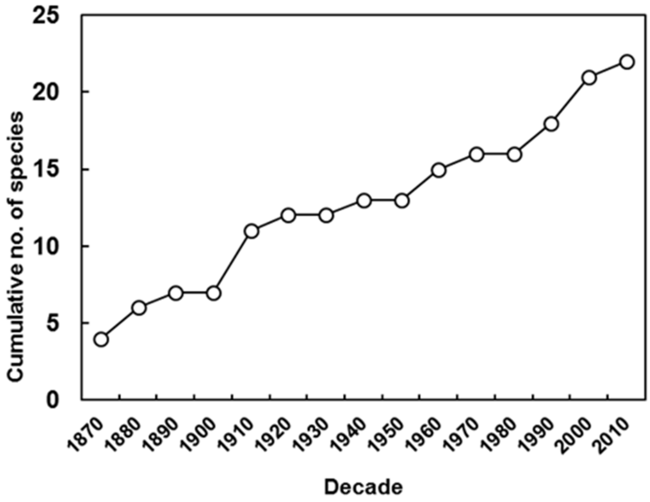

Figure 5-1: Decadal rate of increase for the establishment of breeding populations of introduced freshwater fish species in New Zealand.

The orfe (*Leuciscus idus*) is not known to be present in Northland waters, but a population was established in North Auckland. This is close to the southern border of Northland and this species therefore needs to be excluded. Liaison with Auckland Council biosecurity managers to ensure this risk to Northland is minimised is also advised.

Recent unauthorised introductions of new freshwater fish species to New Zealand include the gudgeon (*Gobio gobio*) and the dart goby. The gudgeon was illegally imported and established in an Auckland pond. It has now been eradicated from that pond, but other stocks may still exist around Auckland.

Weatherloach (*Misgurnus anguillicaudatus*) are not present in New Zealand at present but can be expected to arrive in the future. It is a popular aquarium species and has recently become established in the southeast of Australia (Rowe et al. 2008). The weatherloach is a warm-water species that would thrive in the north of New Zealand and has a high risk of impact in New Zealand waters (Rowe & Wilding 2012). Hence its legal importation is improbable. But it may nevertheless enter the country accidentally (or deliberately) in imports of aquarium fish. There is ongoing interest (reflected in New Zealand Customs intercepts) in the illegal importation of other Asian fish species into New Zealand, especially as immigration increases and interest in the breeding of aquarium fish grows.

Species of the genus *Oreochromis* and *Tilapia* (commonly called tilapia) are also now widely established around the world for aquaculture and are present in Queensland. Similarly, topmouth gudgeon (*Pseudorasbora parva*) and ruffe (*Gymnocephalus cernua*) have been recently spread throughout Europe mainly in ship ballast water. The topmouth gudgeon has been introduced to 32 countries (from Central Asia to Europe and North Africa) in less than 50 years, so can be expected to be illicitly or accidently imported to New Zealand in the future. Other species of concern include the black spotted goby (*Neogobius melanastomus*) introduced to a number of countries also via ship ballast water, the armoured catfish (*Pterygoplichtys* sp.) a popular aquarium species, and the snakehead (*Channa argus*), swamp eel (*Monopterus albus*), and mud cat (*Pylidictis olivaris*). These species have all been introduced to a number of other counties for aquaculture. Roach (*Rutilus rutilus*) were historically introduced into Australia for sports fishery purposes.

At present the legislation for the legal importation of new species of fish to New Zealand provides good safeguards to prevent potential pest species being deliberately introduced for aquaculture or sports fisheries. Accidental and deliberate illegal introductions are therefore the main vectors for cross-border importation of these species. Ponds and lakes in or close to major population centres are where such species were first found in Australia (Rowe et al. 2008), therefore surveillance to detect illegal entry needs to be focussed on similar environments in New Zealand.

6 Key issues

Knowledge of the threats posed by introduced fish to Northland waters indicates that the current key biosecurity risks are the spread of perch and koi carp. The further spread of gambusia also needs to be addressed even though it is now widespread throughout the region. The spread of rudd, tench, and catfish to lakes where one or more introduced species are already present is also a concern as multiple-species communities provide a greater threat to water quality than a single species population.

The risk to Northland lake water quality and ecosystem services posed by perch and koi carp can be reduced by a policy of progressive eradication to exclude these species from Northland. This is also applicable to tench because there are few populations of this species present in Northland, and those that are present appear likely to be amenable to eradication. The other species (goldfish, catfish, rudd, gambusia) are more widespread and so eradication is no longer feasible. A policy of containment is therefore appropriate in the short term, but this must recognise that tools for the efficient control or eradication of such species are likely to be developed in the future. Containment also implies the need for the development of appropriate monitoring and tools to prevent any new incursions.

A major immediate concern at present is the possible extinction of the dune lakes galaxias by gambusia in the three Kai Iwi lakes near Dargaville. As the dune lakes galaxias is confined to these three lakes and is endemic to New Zealand, its loss from these lakes would constitute a global species extinction; the first in New Zealand since the disappearance of the grayling. Accordingly this species has a high threat status and is the subject of a DOC recovery plan, which is currently under review.

The dune lakes galaxias in one of these three lakes (Lake Kai Iwi) is now extinct as this lake has been completely overrun by gambusia for many years and there are few or no trout present there to keep gambusia in check. Alternatively, or in addition, the proliferation of rushes around this lake protects the gambusia from predators allowing the development of a high density population. The high density of gambusia around the entire edge of this lake will have decimated the dune lakes galaxias and, over time, driven it to extinction.

Although the stocked rainbow trout in lakes Waikere and Taharoa are thought to have reduced the dune lakes galaxias through predation, such predation has also occurred in Lake Ototoa for many years. However, the closely related dwarf inanga population present there has remained abundant. The role of trout in the decline of the dune lakes galaxias in Lakes Taharoa and Waikere is therefore now in doubt. Whereas trout may well have had a role in the decline of the dune lakes galaxias in these lakes, trout predation was not responsible for this species' disappearance in Lake Kai Iwi. Some other factor must be acting in concert with trout, and gambusia is the most likely candidate. The temporary cessation of trout stocking in Lake Waikere resulted in a marked increase in gambusia during summer months raising the possibility that trout may keep gambusia densities low. A low trout stocking rate is therefore maintained by the Northland Fish & Game Council in lakes Taharoa and Waikere until the role of trout in maintaining a species balance in these lakes can be confirmed/discounted. The proliferation of rush beds in these lakes also needs to be controlled as they provide good protection for gambusia and may increase its distribution and density in these lakes to the detriment of the dune lakes galaxias.

The recent (2001) finding of gambusia in Lake Rototuna raises the possibility of the eventual disappearance of dwarf inanga in this lake as occurred for the dune lakes galaxias in Lake Kai Iwi. Rowe & Chisnall (1997) noted that whereas the dwarf inanga occurred in only 12 Northland lakes, it was rare or extinct in 8 of these, hence its future viability was also precarious. The likely loss of the population in Lake Ototoa and future loss in Rototuna will further reduce the number of viable populations and increase this species' extinction risk.

The fate of the dwarf inanga in Lake Rototuna is yet to be determined. It will provide a useful test for the effects of gambusia on dwarf inanga in the absence of trout predation. NIWA has historic data for this lake showing that dwarf inanga were relatively common in the 1990s. A new survey (using the same methods and effort as used routinely in the 1990s) is required to update the status of the dwarf inanga in Lake Rototuna.

The further spread of gambusia to the other Poutu dune lakes further south is a real concern for Northland and needs close attention by both DOC and the Regional Council. Gambusia have been reported from a small stream near Poutu so could be spread northwards from here, unless it can be eradicated from the Poutu Peninsular.

The status and effects of the dart goby now present in the lowland reaches of a coastal stream in Tom Bowling Bay (and the Great Barrier Island) needs to be identified to determine whether the presence of this species provides any cause for concern. If so, these populations should be eradicated. It could be argued that eradication on a precautionary basis (as occurred for the gudgeon in an Auckland pond) is advisable as it may be more feasible and less costly than establishing proof (or not) of impact. A 'shoot first, ask questions later' policy may therefore be more practical.

The current status of the caudo in Northland also needs to be determined as this species has the capacity to become another 'gambusia'. If it is present in the wild, then eradication would be warranted, especially as this would be the first incursion in New Zealand and its eradication would prevent any further spread to the rest of the country.

In the future, there will be an increasing demand for irrigation dams to store water in New Zealand and Northland will be no exception. The proliferation of small, shallow and soft bottomed reservoirs and ponds resulting from this trend will provide a greater range of habitats for the introduced fish species present and, coupled with immigration and increased human population, it can be expected to increase pressure to stock these waters with fish other than trout and eels. The long-term consequences of this would be a deterioration in the quality of water in these environments and the inevitable downstream colonisation of the river network in which they occur. Policies are therefore needed to address this future risk. In particular, good public education is required to underpin and gain wide acceptance for biosecurity policies that protect water quality and ecosystem services (along with biodiversity) through restricting the further spread of introduced freshwater fish. However, these policies need to be evidence-based in order to gain public acceptance and compliance. Evidence of impact is also required if such policies are to withstand legal challenge.

The keystone management action for a good biosecurity strategy for freshwater organisms is rapid detection and response. This is because lakes, ponds and even river networks are biological islands within a terrestrial landscape. Dispersal of introduced fish across this landscape requires the lifting of the boundaries between the aquatic islands by human intervention (deliberate, accidental or illegal). If the primary introductions are targeted through rapid detection and response, then secondary dispersal will not occur. Given this reality, effective biosecurity action needs to include provision for targeted monitoring and the capability for a rapid incursion response when a new introduction occurs. This will complement targeted public education and provide management effect to Regional Council policies for species containment and/or where possible, eradication.

Targeted surveillance requires the selection of 'at risk' waterbodies and then applying the right methods at the right times (seasons) and right places (habitats) for the species of interest. A preliminary guide on surveillance methods provided to DOC for the main warm-water introduced fish species in New Zealand is shown in Table 6-1.

Table 6-1: Draft sampling protocols for detecting warm-water introduced fish in New Zealand lakes, ponds and reservoirs.

Fish species	Sampling methods	When	Where
Gambusia: (clusters of small fish occupying very shallow, calm waters around the vegetated edges of lakes, ponds and drains)	-Visual observation from pond/lake edge -Beach seining	-January, February, March best -Calm, fine days	- Shallow (<1 m) shelving shorelines with aquatic or emergent vegetation present -Sheltered shorelines -Inspect at least 50 m length of shoreline in total around at least 25% of lake/pond edge.
Rudd & perch: (schooling fish found in surface waters around the littoral zones of lakes and ponds)	-Gill netting (30-100 mm mesh sizes) -Minimum of 4 fine-meshed monofilament panel nets (1 each quadrant)	-Summer months best (Jan-Apr), but sampling possible from Sep-May.	-Lake edge beyond and over aquatic vegetation in littoral zone. -Surface sets in top 2 m of water.
Tench, goldfish, catfish, koi carp: (often solitary fish found near the lake bottom around vegetated lake littoral zones)	-Trammel netting -Fyke netting -Gill nets (50-150 mm mesh)	Summer months best (Jan-Apr), but sampling possible from Sep-May.	-Lake edge at outer edge of macrophyte beds and into sublittoral. -Benthic sets on lake bottom.

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