PROFILE OF WHITE AMUR (Grass Carp) AND SILVER AMUR (Silver Carp) FROM THE RESULTS OF RELEASES IN NEW ZEALAND WATERWAYS.

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BACKGROUND

Grass carp and silver carp have now been present in New Zealand for over 40 years. Their unique potential value as low cost, environmentally friendly alternatives for weed and algae control drove the original introductions by Universities, Government Departments and even one Acclimatisation Society (Hawkes Bay). Once the initial environmental impact assessment studies were completed by the Ministry of Agriculture & Fisheries (MAF) and once the techniques to ensure artificial reproduction had proven successful by the early 1980's, it became time to put the fish to work.

However, any proposed use of these fish was highly controversial at the time. Trout fishing interests were horrified that carp (= crap) might be released into the 'pristine waterways' of New Zealand. The unfortunate explosion of European carp within some American and Australian waterways was largely responsible. North American game management culture has a long history of influence in New Zealand and 'carp' of any type, were all bad. The escape of koi, the Japanese ornamental cultivar of European carp into the Waikato River in the late 1970's gave further cause for alarm. In 1982, MAF undertook a poorly managed release of 2500 grass carp into an insecure location in the lower Waikato. Their subsequent escape into the Waikato River, the only habitat in New Zealand where this fish might possibly have bred, fueled these concerns despite a hasty PR release (McDowall 1982).

Conservation and trout fishing organizations saw 'carp' as rats and opossums of our waterways, foisted upon an unsuspecting public by a MAF agenda to take control of NZ freshwaters. This attitude became entrenched. To cater to political pressures that saw the entire grass carp project in particular, very close to termination, elaborate reporting systems were drawn up to ensure full control by Government agencies over exactly where and when these fish were ever to be used.

Conveniently disregarding the facts that imported humans were fishing in NZ for imported exotic predators (trout), with both species having well-known and major impacts upon native fishes and their habitats, a line in the sand was drawn. Media statements by senior Conservation officials that they were philosophically opposed to any introduction of grass carp were just part of this deep and enduring unease about carp.

Digging a little deeper in to the psyche of the English settlers in NZ, we see that the ability of the ordinary man to shoot deer and fish for trout and salmon was considered important compensation for the serious disadvantages of migrating to nowhere at the opposite end of the world. Game was the preserve of the seriously wealthy upper classes in England. The working classes were left to fish for common carp, roach and rudd, in polluted industrial canals. Small wonder that a visceral response should result from any attempt to lower the class of NZ fishermen by replacing trout with carp.

Over the sheer length of time the grass carp and silver carp biological control programs have now been running, many of the more reactionary second and third generation colonists, with their entrenched attitudes, have simply died off. Younger, better educated administrators with environmental responsibilities may be objective and less intent on ‘fighting’ threats to hunting and fishing. There is also a rapidly growing Asian population, with carp as a welcome component of their culture and cooking.

However, the fact remains that; although the use of Asian carps for biocontrol does work in New Zealand, is frequently much more economic than any other alternative, is environmentally benign and is actually even carbon neutral, a restrictive heritage of extremely tight governmental controls remain upon the use of these fish. There have been staff in government departments and conservation organizations who would assure would-be users that these fish do not work and that they will face major and ongoing costs should they ever wish to try them. Each deterred user was seen as a small personal victory in the task of making sure NZ was kept pure and only filled with native animals (+ trout & deer of course). Such logic ignoreds the fact that humans are exotics and that survival of our present population is impossible without wholescale ecosystem replacement by exotic plants, exotic animals, exotic insects and even fungi and probably bacteria.

Placing the matter in perspective, it is an accepted and widely employed activity to regularly remove the entire contents of small waterways with a hydraulic excavator, placing everything including native fish, upon the bank. Alternatively, herbicide sprays can be used to kill all plants in a single, environmentally disruptive pulse. Meanwhile, an application to release of a shoal of grass carp to simply crop aquatic weeds is still viewed with grave suspicion.

To move away from the fear factor of the 4 letter word CARP, we will follow American protocol in this report by calling grass carp WHITE AMUR and silver carp SILVER AMUR. These names are widely used in North America, in recognition of the Amur River in Northern China, at the northern limit of these species natural range and are intended to differentiate these fish from common carp. Our experience has repeatedly been that even apparently well-qualified fisheries biologists may quickly become confused when asked to pontificate on the subject of ‘carp’.

NZ Waterways Restoration has persevered with the frustrating task of gaining approvals to use white amur and silver amur since they took over responsibility for the fish stocks, following disbandment of Fisheries Research Division in 1992.

1. Overview of freshwater fish in New Zealand

The native freshwater fish fauna of New Zealand is sparse in terms of families (8), genera (10) and species (44) compared to other countries. Many (17) of the 44 native freshwater fish species are diadromous, i.e. some part of their life history takes place in fresh water, and some part in the sea. On streams with barriers to migration, there may be few or no native fishes at all.

From the late 1860s onwards, the fauna was augmented by the introduction of 21 exotic species. There are now 18 self-sustaining exotic species including 7 salmonids plus 3 further species of fish which are not yet known to breed in the wild (including white & silver amur. Thus, in total, the freshwater fish fauna now consists of 65 recognised species. One native species, the grayling (*Prototroctes oxyrhynchus*) vanished in the early 20th Century and is considered extinct.

2. History of White Amur in New Zealand

The University of Auckland introduced a few fish into New Zealand in 1966 for laboratory trials. In 1971 the Ministry of Agriculture and Fisheries initiated a programme to further examine this species' potential as a biological control agent for aquatic weeds. At that time the parents of the present stock were imported as a single shipment of 2000 fish from Hong Kong.

White amur were chosen over alternative species such as Brazilian snails and other weed-eating fish such as *Tilapia* because they were considered unlikely to breed naturally within New Zealand waterways. Control of numbers was thus possible. They offered the potential of a low-cost, long-term and relatively benign solution to aquatic weed problems.

The evaluation of white amur in New Zealand took years and involved a series of trials in static waters such as lakes and reservoirs, and in flowing water such as drains. The ability of the fish to control weed problems in small lakes was first demonstrated in Parkinsons Lake and the Waihi Beach water reservoir (Mitchell 1980, 1984. 1986). Weed control was also demonstrated in a series of trials in agricultural drains on the Rangitaiki Plains (Edwards & Moore 1974) and in the Mangawhero Stream, Akaaka. Since 1992, when management of the species was vested in NZ Waterways Restoration, white amur have been successfully used at a large number of waterways, ranging from Lake Omapere in Northland down to Lake Hood by Ashburton. The value of this fish for aquatic weed control is becoming accepted.

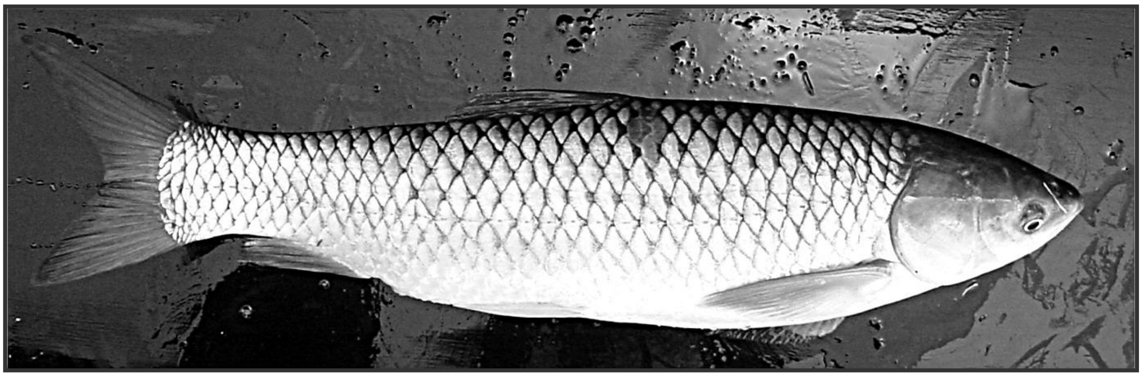
3. History of Silver Amur in New Zealand

The sole introduction of silver amur (from which the entire present entire stock of fish is derived) was made by Hawkes Bay Acclimatisation Society in 1970, when 60 fish were imported. Numbers of fish fell to very low levels (6 fish at one stage) in subsequent years and only the dedication of Andy Carruthers saved the NZ stock. However this series of genetic bottlenecks may mean the vigour and resilience of our stocks are compromised.

Trials were undertaken with MAF support, in hypereutrophic Lake Orakai, to assess the value of the fish for controlling blue green algae blooms. It was shown that if enough fish were present, the phytoplankton crop could indeed be greatly reduced (Carruthers 1986). However further studies were hampered by the sudden death of Andy Carruthers and repeated reorganisations of MAF and it's successor departments.

Since management of the species was vested in NZ Waterways Restoration, a number of promising projects have been considered, in particular, managing blooms in Lake Omapere, Northland. But breeding and rearing this very specialised and highly-strung phytoplankton feeder has proven difficult. With an assured supply of juveniles, it may finally become possible to use silver amur for the role for which they were originally imported, nearly 40 years ago.

4. Species Descriptions



White Amur (Grass carp *Ctenopharyngodon idella*)

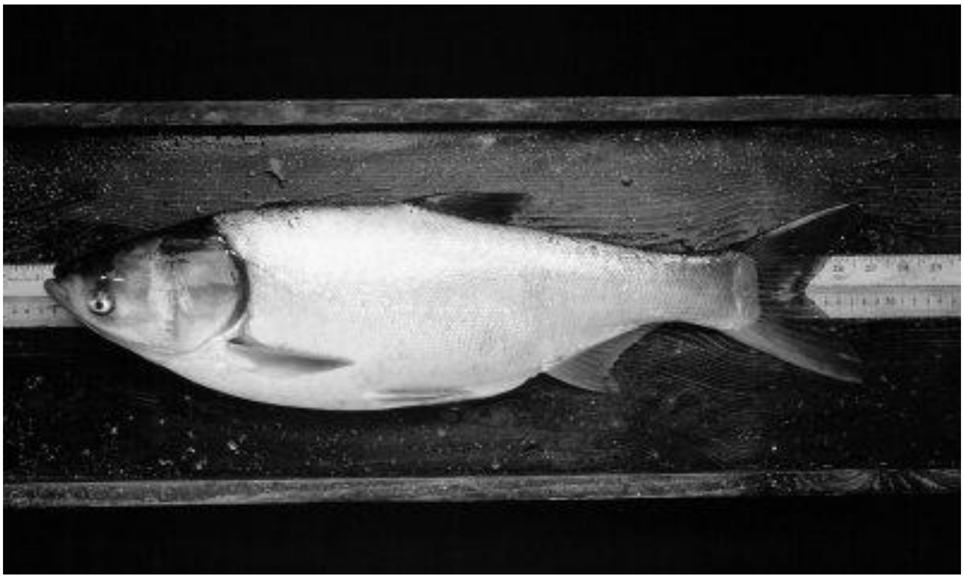
4.1 White Amur

White amur are the largest freshwater fish in New Zealand; reaching at least 23 Kg. The largest specimen found internationally (pre-1989) was 35 kg. This fish belongs to the carp family (Cyprinidae), one of around 20 000 diverse species in this large family.

Body shape: almost cylindrical, with flat head and round abdomen. Scales: large. Mouth: terminal; lower jaw, shorter. Gill membrane: connected to isthmus. Gillrakers: small and short, in a scattered arrangement. Pharyngeal teeth: two rows in 2,5/4,2, heavily built and compressed like combs. Intestinal length: 2.3-3.3 times body length. Colour of body (alive): dorsal, grey; abdomen, yellowish white; sides, silver-greenish yellow; fins, a lighter colour.

Unusual among fish, a herbivorous species, consuming all sorts of aquatic and terrestrial plant material.

4.2 Silver Amur



Silver Amur (Silver carp, *Hypopthalmichthys molitrix*)

Silver amur are distantly related to white amur, both are members of the family Cyprinidae. Silver amur have grown to 12 kg in New Zealand. Unusual among fish, a planktonivorous species, filtering plankton from the water.

Body shape: laterally compressed with a deep body and a large head (29-33% of SL). Scales: very small. Mouth: large, terminal and lacking in any teeth. Lower jaw longer. Gillrakers: highly modified to form a complex array of filters capable of removing plankton from the water. The gillrakers are fused to form a sponge-like filter and an epibranchial organ secretes mucus over the filters, which assists with trapping small particles. A strong buccal pump (the fish breathing reflex) forces water through this filter. Particle selection is thought a passive mechanical function of gill raker morphology. Some authors consider these fish can filter particles down to 4 microns, others consider they cannot effectively consume algae <20 microns and select large algae (the bloom forming toxic blue green algae are large and frequently grow as clumped colonies). Because they have no stomach, silver amur feed more-or-less continuously. Intestinal length: extremely long - 7-10 times body length. Silver amur have natural defences against the strong biotoxins produced by blue green algae and can sometimes contain sufficient algal in toxins their systems that they themselves may be hazardous to eat.

Colour of body (alive): dorsal, dark grey; abdomen and sides, bright silver; fins, dark grey to light grey (stress/high blood presure in freshly caught fish leaves the pelvic, ventral and caudal fins pink).

5. Native habitat of White and Silver Amur

Both white amur and silver amur are indigenous to some of the great rivers of China, being distributed throughout the Pearl River, Qiantangjiang River, Changjiang River, Huiake River and northwards up to the Amur and Heilongjiang River systems.

6. Breeding biology of Chinese carps

In their natural habitat in China, white amur and silver amur feed in the slow-flowing lower reaches of rivers and in associated lakes. Spawning begins with the onset of the monsoon season (early-summer). Age and weight distribution of spawning schools varies with the region. In the southern Pearl River, sexually mature fish are generally smaller and mature earlier than in the northern Changjiang River (by 1 to 2 years). Prespawning schools of Chinese carps gather in the monsoon season and migrate hundreds of kilometres upstream towards the middle and upper reaches of these very large Rivers. And spawning will only occur once ecological conditions at the spawning grounds are fully suitable.

By this time the monsoon floodwaters are rising. Fish congregate in large schools below rapids and other high turbulence sites such as below bridge pilings, and then spawn en-masse. Unlike koi or goldfish, the eggs of these carps are separate and non-adhesive. Fertilised eggs expand enormously by absorbing water through the egg membrane and become plump, transparent, and elastic. The yolk becomes a small portion of the entire expanded egg, which in this way achieves a density close to water. As a result eggs are semi-buoyant in the turbulent river current, remaining suspended in the moving water column until the fry hatch. But having a specific gravity that still remains slightly greater than water, eggs sink to the bottom in still water and die. Hatching time varies inversely with temperature, ranging from 18 hours at 28 ^{o}C up to 60 hours at 17 ^{o}C. Temperatures below 20 ^{o}C result low survival with virtually all larvae hatching being deformed.

Larvae are very undeveloped at hatching with non-functional eyes and mouth. They remain drifting in the river pelagic zone for a further 3 days, staying in suspension by regular bursts of vertical swimming. By this time larvae have developed to the feeding stage and have been carried hundreds of kilometres back downstream and out across the enormous inundated floodplains of these monsoonal rivers. The warm, newly flooded wetlands that develop at this time bloom with the small crustaceans eaten by fish fry. White amur fry, together with silver amur and a range of other Chinese carp species with identical spawning ecology, are perfectly placed to exploit this bounty. Initially fry (4-40 mm) in length feed mainly on zooplankton. Fingerling white amur (40-250 mm) gradually become herbivorous and at this time first begin to consume tender aquatic plants, filamentous algae and duckweeds.

Given the maximum water temperatures (28^{o}C) and minimum water velocities (0.6 m/s) needed for egg survival, 50 km of river is thought the minimum distance required for successful egg hatching. The three day long mesopelagic larval stage is the next consideration, requiring a further distance of flowing water. In practice, successful reproduction of stocked white amur has only been reported in long rivers, the two shortest of which are the Kara Kum Canal (USSR) and the Tone River (Japan). The Kara Kum Canal is 80-100 km and eggs do not hatch when water temperature falls below 18.5 C, while the Tone River is 370 km long with wet season water temperatures ranging around 20-21^{o}C. This population has since collapsed with flood works and river diversion (M. Ito pers comm.). Naturally reproducing populations of white and silver amur have now been recorded from the lower Mississipi and Missouri Rivers, very large rivers closely similar to their natural habitat. Where successful reproduction has occurred, no observable impacts have been reported despite considerable alarmist rhetoric. No natural breeding has ever occurred in still waters.

Could amur carp breed in New Zealand ? New Zealand's longest river is the Waikato, at 425 km, followed by the Clutha (322 km) and the Wanganui (290 km). The Waikato and Wanganui do have summer water temperatures of 20-22^{o}C, whilst the Clutha only briefly reaches a high of 17^{o}C. The Waikato and Clutha Rivers are truncated by dams, while none of our rivers has an annual summer flooding cycle, nor any significant remaining area of lowland wetlands for retention and rearing of fry.

It is generally accepted that the risk of these fish forming naturally spawning populations in NZ is nil.

7. Age, size and growth

Growth rate is highly variable. It is dependent upon temperature, suitable food supplies and water quality. Released stocks appear to have an effective life span of approximately 10 years although individuals can live for 20 years or more. White and silver amur appear to grow to an average size of 10-15kg under favourable conditions (primarily adequate food and space) in Northern New Zealand.

8. Feeding habits

8.1 White amur

These are highly unusual fish in that adults are herbivorous. They consume all sorts of aquatic and terrestrial plant material; hence the typical cyprinid pharyngeal teeth have become well developed, tough, and strong. These grinding 'teeth' in the back of the throat are shaped like choppers with blunt, saw-toothed edges. Pharyngeal teeth from both sides of the throat are interlaced and work against the callous basioccipital pad on the roof of the throat, grinding plant material into fragments for digestion in the intestine.

White amur are voracious eaters of plants, but cannot digest cellulose. Faecal pellets show the food is processed, leaving a skin of soft green material surrounding a bulk core of light-coloured cellulose fibre.

Even adult white amur (greater than 250 mm) prefer tender succulent plants and avoid large fibrous plants such as flax or old raupo (Typha orientalis) stalks, plus blister raising species such as Ranunculus and water cress. Water lilies (Nymphaeaceae) also appear to be avoided by this fish. In New Zealand trials, the species of plants readily eaten by adult white amur included oxygen weeds, pondweeds, marginal and aquatic grasses and most floating weeds. Based upon results from a wide range of sites stocked in New Zealand, white amur plant preferences are shown in the following table.

Table X. Preferences of white amur for the plant species in NZ waters

Plant Group	Most preferred food	Palatable to the fish	Eaten by the fish	Last resort as fish food
Grasses	*Glyceria fluitans* *Glyceria maxima* *Paspalum distichum*			
Oxygen plants	*Hydrilla verticillata* *Elodea canadensis* *Lagarosiphon major*	*Ceratophyllum demersum* *Myriophyllum* (native spp.)	*Egeria densa*	
Pond plants	*Potamogeton* (many spp.) *Callitriche stagnalis*			
Floating leafed plants	*Lemna major* *Aponogeton distachyon* *Spirodela punctata* *Wolffia australiana*			*Azolla rubra* *Nymphaea alba* *Hydrocleys nympaeoides* *Salvinia natans*
Emergent plants	*Eleocharis* (three spp.)	*Typha* (Juvenile) *Baumea articulata*	*Ludwigia palustris* *Myriophyllum* (exotic spp.)	*Typha orientalis* (adult) *Polygonum decipiens* *Ludwigia peploides*
Algae (macrophytic)	*Spirogyra* (many spp.) *Cladophora* (many spp.)	*Nitella hookeri*		*Chara* (three spp.)

8.2 Silver Amur

The food preferences of silver amur are less well known. Algae species composition in a water body can vary rapidly. These plants are also microscopic and need expertise for identification.

From an examination of faecal strings it was reported that blue green algae colonies made up much of the fishes diet in New Zealand (A.Carruthers pers comm.). Numerous studies have been done overseas on the effects of stocking silver amur on algae blooms. Results have been variable ranging from excellent control to an apparent exacerbation of the problem. It is now generally considered that the existing structure of the zooplankton-phytoplankton community is highly important for the success of phytoplankton control by silver amur. The pre-existing presence of large herbivorous cladocera and the use of silver amur biomass higher than 200kg.Ha have been found to be unfavorable conditions for biomanipulation. But where micro-zooplankton are dominant, the effects of silver amur predation on zooplankton is insignificant while cyanobacteria development is reduced owing to the cropping activity of the fish (at up to 180 kg.Ha silver amur biomass).

Large cladocerans are unusual in New Zealand waterways. The predation pressure of native fish such as smelt naturally forces zooplankton communities towards micro-zooplankton. As micro-zooplankton are ineffective at grazing large algae, silver amur have a role in these types of waterway in New Zealand for algae control and could be expected to enhance the food webs feeding larval native fish by removing large algae colonies. Dominance by micro-algae can be expected to develop after silver amur stocking, leading to enhanced production of micro-zooplankton. Common and crans bullies have small (3 mm) larvae which feed upon micro-zooplankton (rotifers/copepod nauplii). Populations of these native fish have been found to reach high densities in silver amur ponds in New Zealand (G. Jamieson pers comm.).

9.0 POTENTIAL IMPACTS FROM THE INTRODUCTION OF WHITE AMUR TO A SITE

The major perceived potentially adverse impact of the introduction of white amur to a site is that the fish will consume all aquatic plants at that site. This impact can be achieved and is often desired. Obviously any adverse (or beneficial) impacts result because of the total removal of aquatic plants. Not that they have been removed by white amur per se. Total removal of aquatic plants can also be achieved by use of chemicals and sometimes by mechanical control. Allowing eutrophication to proceed unchecked can also totally replace aquatic plants with algae (including the toxic blue-green species)

This perception particular to the use of white amur arises from concerns that numbers at a site cannot be reduced if required. Reduction in fish numbers is to some extent dependent on the physical characteristics of the site. But white amur have now proven relatively easy to catch in ponds, larger dams and even in lakes. Eventually, any problem will be resolved by fish mortality.

Removal of stocked amur is accomplished by netting. The best catches have been from using rag mesh or fine multi-strand mesh with no weighted bottom lines. Nets are set at a minimum of 150% mesh depth to bottom depth in shallow weeded areas. These soft, fine nets are used because they result in minimum damage to the fish and allow easy release of any by-catch. In the Northern North Island, by-catch will be very largely confined to low numbers of larger grey mullet as mesh sizes used range from 125mm to 175mm. No other fish common in these eutrophic warm-water habitats are large enough to be caught in the nets. Fishing will be concentrated in still water rather than flowing water sites (which is where mullet appear to concentrate in freshwater). All nets and methods comply with Ministry of Fisheries Special Permit 396.

These standardised methods of netting fish may also be supplemented in future by the use of selective white amur bait (Prentox©), which has shown promising results.

9.1 Known impacts on the NZ environment

Beginning in 1971, the New Zealand Government conducted prolonged studies investigating the effectiveness of white amur at removing troublesome weeds and their impact on the environment and biota.

White amur proved effective at totally eliminating areas of palatable pest aquatic vegetation from a water body, once their feeding rate exceeded the plant growth rate. These studies showed that the major impact is the total removal of aquatic vegetation, if fish numbers are too high relative to the plant regeneration rate. This actually had value for total eradication of monoclonal exotic weeds and has allowed lake restoration projects impractical by any other methods. No evidence has been produced that the fish have direct harmful effects upon either native biota or introduced salmonids. All studies suggested that the known impacts of white amur were less than or no more damaging than weed removal by other common methods such as the use of excavators or the use of chemicals. The overall level of impact hinged upon appropriate control for the site.

No evidence has ever been produced to suggest that white or silver amur are likely to spawn and develop permanent populations in New Zealand waters. Since the initial New Zealand impact assessment on white amur was completed in 1985, it has become apparent that concerns expressed at that time about their ability to reproduce in large rivers outside their natural geographic range were overstated. Global experience indicates that successful reproduction by white amur outside their natural range is extremely rare.

9.2 Potential impacts on plants

The major potential impact is that all aquatic plants present at the introduction site will be consumed. Further, that all plants that subsequently grow will likewise be consumed before they can achieve any noticeable growth and the site will be completely barren of plant life until the fish die.

This potential adverse effect can arise only if high stocking densities are used and if fish numbers are not subsequently reduced as weed densities are reduced.

Total removal of introduced nuisance plants from an area can be beneficial if the area can be recolonised by favourable species. For instance, Wells et al (1999) reported that in Lake Parkinson, where Egeria densa was eradicated, native plants re-established naturally from the residual seedbank. In addition, all fish (including all white amur plus unwanted coarse fish – rudd & tench) were removed with rotenone and native fish restocked.

9.3 Impacts on exotic fish

Weed removal by white amur (or by any other method) may affect introduced coarse fish species, such as rudd, tench, goldfish and perch, which require weed beds for spawning. In New Zealand, this is not generally considered an adverse impact.

Interactions between white amur and trout are generally limited because carp prefer warmer feeding waters. In rivers carp prefer the warmer lower reaches. Trout prefer cool, flowing water in areas further upstream. In lakes, both species will occupy the littoral zone but feeding areas and food will differ because trout are carnivorous and carp are essentially herbivorous. Opponents of the use of white amur suggest impacts may occur following removal of plant species in the littoral zone, which could expose juvenile trout to predation. The importance or otherwise of exotic aquatic plants for juvenile trout survival in lakes has in fact, never been demonstrated.

9.4 Impacts on native fish

Rowe and Schipper (1985) discussed the potential impacts of white amur. The fish did not prey upon fish except when trout fry were fed to starved juvenile fish in bare aquariums . Eels, bullies, smelt and galaxiids survived and grew well in trial lakes denuded of vegetation and stocked in shallow aquaculture ponds which lacked protective cover, but contained large, starved white amur (Mitchell pers obs). Bullies attained pest densities under these conditions. Although some galaxiids require briefly flooded marginal vegetation for spawning, this would not in reality be accessible to white amur. White amur cannot survive in 15 ppt salinity (50 % seawater); even lower levels are likely to repel fish. Native fish in lakes and ponds stocked with white amur displayed faster growth, large size at maturity and high survival (Mitchell 1986).

As white amur are herbivorous it is unlikely that predation on native fish would occur. White amur could consume eggs of indigenous species adhering to aquatic plants. However, apart from common bullies, native species generally do not lay eggs on plants and those that do, spawn in tidal or briefly flooded terrestrial vegetation. And in fact, common bullies were found to develop to pest densities in white amur aquaculture ponds. Because they cannot tolerate saline water, white amur are not considered any threat to the ecology of estuaries.

Large longfinned eels are the top native predator in NZ freshwaters. White amur have co-evolved with eels in Chinese river systems and there is little evidence that established fish suffer significant predation. However eels are territorial and even starving white amur carp in ponds will avoid vegetation containers occupied by a resident eel.

9.5 Impacts on birds (waterfowl)

Various waterfowl feed in part on submerged aquatic plants. Black swans and Canada geese are largely herbivorous and so are the species most likely to be affected by weed removal. Prestocking surveys at a number of lakes where exotic weeds have become problems have often found populations of black swans. These birds tend to graze the weeds down to a uniform depth of about 1 m. below the surface. Dispersal by hunting or seasonal migration can result in sudden weed problems as this previously grazed ‘lawn’ reaches the surface all at once.

Most other waterfowl are omnivorous and feed on a range of aquatic and terrestrial plant species, together with associated invertebrates. Other omnivorous birds potentially affected by plant removal are grey duck, grey teal, mallard duck and shoveler duck. All waterfowl are highly mobile. Complete weed removal by overstocking an area with white amur may force waterfowl to move elsewhere to feed. Farmers may object if (as often occurs anyway) white amur displace water fowl which then shift onto adjacent pastures.

Shags, herons and kingfishers all eat fish. Control or exclusion of these birds has been found essential when rearing both Chinese carps. A lower size limit of 250 mm is recommended for stocking to reduce the impact of shag predation. However, larger white amur can bear wounds from shag attacks. The endangered bittern can also be assumed a potentially serious predator on Chinese carps. Predation by mallard ducks working as a team has been found to be a problem in white amur rearing ponds.

9.6 Potential impacts upon other animals

Weed removal and a loss of cover may affect various aquatic animals, including native species, by increased predation or a reduction in invertebrate prey.

Weed dwelling invertebrate populations would be reduced by weed removal. The small aquatic lepidopteran *Nymphula nitens* is the most obvious species. Grazing invertebrates such as snails, may be important foods for fish. However native fish are opportunistic carnivores and were found to shift to benthic foods such as midge larvae that became more available with weed removal (Mitchell 1986).

There are no reports of invertebrate populations declining significantly as a result of direct white amur predation. Freshwater mussels will probably benefit from better water circulation and a possibly richer phyto-plankton.

9.7 Potential impacts on water quality

Significant changes in water quality can occur when aquatic macrophytes are eliminated or greatly reduced. Beds of anaerobic silt build up beneath exotic macrophyte beds owing to the rapid growth and decay of the massive plant biomass in the water column above. Removing these plants exposes accumulated silts to the water column. In small water bodies this may lead to an increase in turbidity depending on the type of bottom, wave action and the quality of the inlet water (Mitchell et al 1984). This effect is common to all weed removal methods.

Ensuring that a band of emergent plants remains around the perimeter of small water bodies can reduce potential adverse effects by trapping external silt and nutrient loading. At rural sites this usually requires fencing to protect shallow water and emergent plants from livestock browsing. Although they will be prevented from future encroachment in to open water, marginal emergent plants are retained in shallow water and maintain the natural character of the water body.

9.8 Potential impacts on the natural character of a release site

It is considered that any major potential impacts on natural character will be confined to areas of high quality aquatic habitats containing only native plant species. Such areas have usually been protected until the present by sheer isolation. It is not anticipated that approval would be applied for nor given for transfer of white amur into such areas. Most projects are intended to eventually restore native plant communities.

In other locations controlled use of white amur to remove nuisance plants, removal of the fish and subsequent establishment of beneficial native species, has had a positive impact on the values of that location.

The provision and maintenance of a suitably sized band of emergent plants around the boundary of a lake or pond or along the banks of a stream or drain will help to maintain the natural visual character of an area. This may require commitment to riparian fencing.

In our opinion, total removal of introduced nuisance plants is not seen to be contrary to the natural values of an area, provided protection of a riparian margin is considered.

9.9 Potential impact of escapes

Could escaped white amur have significant undesirable impacts?
There is potential for a change in ecological values to occur as a result of low density preference feeding by major escapes into small water bodies. This could result in a shift in plants dominance or a decline in a rare species. In reality, white amur are stocked to a density where they can exert weed control. Escaped fish will be at much lower stocking densities in a wider environment. The experience has been that they have then had nil impact.

However, any potential impact of escapes must be prevented by secure arrangements to contain the white amur within the release site.

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