Some issues in risk assessment reports on grass carp and silver carp

J S Clayton, R D S Wells
National Institue of Water &Atmospheric Research Ltd
PO Box 11-115
Hamilton
New Zealand

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1. Introduction

Grass carp *Ctenopharyngodon idella* and silver carp *Hypophthalmichthys molotrix* are commercially available to waterbody managers for control of aquatic weeds and planktonic algae, respectively, subject to approval from DOC, the Ministry of Fisheries, and in consultation with Iwi, the public, and Fish and Game New Zealand.

Silver carp consume planktonic algae, but have also been reported to consume larger zooplankton (Wu *et al.* 1997; van der Zweerde, 1993, Cooke *et al.* 1993) and have been shown to be associated with increases in chlorophyll a levels. Consequently the introduction of silver carp is often highly controversial (Leventer & Teltsch 1990), and their use in Israel and the USA is likely to remain restricted as they may cause more problems than are solved (Cooke *et al.* 1993). A sustainable decrease in algal numbers has not yet been demonstrated in New Zealand waters from experimental use of silver carp. The work by Carruthers (1986) showed photographic evidence of an effect, but there were no data to show that such an effect was sustainable (Rowe 1989). The New Zealand experience with use of silver carp has been limited, and effects on aquatic ecosystems (zooplankton or larval fish densities in particular) have not been evaluated. Proposals for the use of silver carp should therefore be approved for experimental purposes only, so that information can be obtained on both their potential to manage algal problems, and on their possible environmental impacts. As silver carp have not been shown to be an acceptable or effective management tool for algal control in New Zealand to date, the rest of this report focuses on grass carp.

Grass carp have been an effective management tool for removing aquatic vegetation in many countries around the world. The New Zealand experience with use of grass carp has confirmed the valuable role that these fish can play in managing waterbodies, particularly where total vegetation removal is a desired outcome.

Grass carp have been released into New Zealand waterbodies for quite different objectives:

Eradication (as opposed to control) of an exotic weed when the target species reproduces by vegetative means only. In Lake Parkinson, grass carp eradicated *Egeria densa* and removed most other aquatic vegetation. Following removal of the grass carp, native species regenerated from seed banks in the sediment and the lake was restored to its former state (Rowe & Champion 1994, Tanner *et al.* 1990). Where eradication of a targeted weed species is proposed, short-term undesirable impacts may be acceptable in view of the long-term gains.

Long-term control of weed species where eradication is not feasible. In such cases impacts are likely to be ongoing and can be weighed against other control options. The recent development of **Prentox®** (rotenone-spiked food pellets) has the potential to better regulate grass carp stocking densities for more effective long-term weed management or allow re-capture where impacts prove unacceptable.

With any release of grass carp, there are risks of undesirable outcomes. Rowe & Schipper (1985) produced an assessment of the impacts of grass carp in New Zealand waters. They stated in conclusion (page 146): 'If the owners of ponds, dams, or drains wished to maintain the wildlife values of these waters, and control water weeds, they would be advised not to use grass carp until partial (versus total) weed control by the use of these fish can be demonstrated. In lakes, and large reservoirs, weed removal has the potential to create more serious effects because these waters often contain valuable wildlife and fisheries resources. Hence the need for a detailed assessment of the potential impacts at each site prior to releasing them. DOC requires applicants wishing to stock grass carp to provide a risk assessment report (RAR). Suggested content for the RAR is:

- A detailed species profile of the biological control agent proposed for introduction, including its requirements, habitat preferences and account of previous use in similar situations.
- Details of the site for release (location, size, and waterbody characteristics) and any areas the species might access if they were to escape.
- A comprehensive list of the values and uses of the waterbody and where relevant how these are related to the ecological functioning of the waterbody.
- A complete (animal and plant) species inventory for the release site with specific consideration of how significant the biota are locally and nationally and how representative they are.
- Detailed information on why the fish are required and the advantages of using the fish as a biological control agent for the site in question.
- Details on the target plant species, and comment on how effective grass carp are likely to be at removing the target species at the site.
- A comparison with alternative techniques for controlling the target species, including information on their likely level of success and their effects on the environment.
- An assessment of the possible impacts the fish might have on the ecology of species present and other characteristics of the release site.
- The possible impacts that might occur in other waters should the fish escape (a worst-case scenario should be considered).
- Details of the operational plan, describing how the fish will be managed in a way that ensures that they achieve their purpose, and cause minimal adverse environment effects, and that their risk of escape is minimised. Key elements are stocking rates, monitoring, details of fish removal if required, measures to prevent escape, and procedures if they do escape.

2. Issues

2.1 ASSESSMENT OF POTENTIAL EFFECTS OF GRASS CARP ON NATIVE FLORA AND FAUNA

Comment

Although many people are more interested in native than in exotic species, exotic species can be valuable in their own right, or for providing habitat for other species that would not exist without their presence. In many lowland habitats, exotic "weed" species are the last remaining vestiges of any macrophytes capable of growing in eutrophic conditions. The following comments on the potential effects of grass carp on flora and fauna emphasise the range of potential effects that grass carp may have on native species, but include mention of effects on valued exotic species.

Potential impacts on plants

Submerged aquatic plants are important primary producers in river and lake ecosystems. They play a major role in providing habitat, and may provide a food source for fauna. They provide surfaces for attachment of periphyton, which is a major source of food for snails, and plants also provide ecosystems with much detritus, which is a food source for many other organisms. Additionally they have a physical role by affecting the hydrology of the waterbody, sedimentation rates and re-suspension of fine bottom sediments as well as acting as a buffer zone for nutrients and pollutants between land and water.

Grass carp have the potential to consume all aquatic plant species found in New Zealand waters (Rowe & Schipper 1985). Plant species preferences result in preferential removal of some species (Cassani 1996) and, in New Zealand, native charophytes are known to be a preferred species for grass carp (Edwards 1974; Rowe & Schipper 1985). Low-growing aquatic plant species in gently shelving, shallow (<0.2 m deep) water may not be grazed to a significant level (Clayton et al. 1992). On the other hand, terrestrial vegetation can be grazed by grass carp in steep-sided waterbodies or drains where it hangs into the water (Rowe & Schipper 1985). Overall, the general result in the area of release is total vegetation removal (>95%) which has been reported in the US at densities from as low as 7 fish ha^{-1}, although in other situations not until densities of 180 ha^{-1} (Cassani 1996).

Potential impacts on invertebrates

Grass carp probably consume some invertebrate species on plants in the process of eating the vegetation and have been known to feed on some crustacea following weed removal. However, of greater significance, the consumption of plants removes the habitat for fauna reliant on the presence of macrophytes.

The removal of aquatic plants (by grass carp or other means) can also bring about undesirable changes in invertebrate communities, such as an increase in the numbers of benthic invertebrates including midges. Although they may benefit fish production, midges can become a nuisance and form dense swarms which are atttracted to houses at night.

Macrophytes provide a source of detritus used as food for many invertebrates including koura and snails. Gastropods can exist at very high densities amongst macrophytes, which provide leaf surfaces and detritus for them to graze. The freshwater shrimp (Paratya) often occurs in large numbers in macrophyte beds in flowing water. Even zooplankton (such as *Cladocera*) avoid predation by seeking refuge in macrophytes. High levels of weed removal using grass carp or other means can therefore have an affect these invertebrates.

There are also some unusual invertebrates which benefit from or are dependent on aquatic plants, such as the freshwater limpet and the freshwater crab. Collier (1993) has reviewed the status, distribution and conservation of freshwater invertebrates in New Zealand. While there are rare and endangered species, little is known of their life cycle needs or distribution. Collier emphasised that a species-orientated approach to aquatic invertebrate conservation was not appropriate. He advocated not only the conservation of rare and endangered assemblages of aquatic species but representative aquatic habitats covering a range of environmental gradients (focusing on areas of high invertebrate biodiversity). In this respect the removal of large areas of aquatic plants (by grass carp or other means) in the long term could threaten invertebrate biodiverstiy if representative aquatic habitats are not set aside and protected.

Potential impacts on fish

Grass carp do not prey on fish in natural environments. In New Zealand, grass carp interactions with trout, bullies, smelt, tench, rudd, and galaxiids were studied in Lake Parkinson and in the Waihi reservoir. Eels, bullies, smelt, and galaxiids have survived and grown in the presence of large (> 250 mm) starved grass carp. Bullies have been observed to spawn successfully in ponds which contained high densities of feeding grass carp (Rowe & Schipper 1985). Smelt in lakes and probably rivers shed their eggs over open sandy substrates and so their areas for spawning may be enhanced by weed removal by grass carp. Some fish species lay their eggs amongst or on the macrophytes. Species such as carp, perch, and rudd attach eggs to plants. Bullies can spawn on macrophytes, although they generally prefer hard rocky surfaces.

It is the indirect effects of extensive long-term weed removal that could most impact on fish. The young stages of many fish also are dependent on macrophytes for shelter from predation, or rest from water flow. Migrating whitebait have been observed in streams over macrophytes and utilising the vegetation for cover when threatened (authors' observations). Many fish benefit from the presence of aquatic plants, which can provide a large supply of invertebrates for food. Weed-dwelling macro invertebrates would be reduced by weed removal. On the other hand, excessive growths of macrophytes can cause oxygen depletion, and invertebrates and fish, unable to move away, may die. Also most native fish are opportunist carnivores and will feed on benthic foods such as chironomid larvae in the absence of vegetation.

Rowe & Schipper (1995) considered the effects grass carp might have on trout in New Zealand. They concluded that in small shallow lakes there is some potential for weed removal to adversely affect trout populations and their food resources, but there is also scope for it to have positive effects. The lack of significant, direct, adverse competitive or predatory interactions between grass carp and trout, and the fact that exotic weed beds could well restrict the habitat for trout, both tend to indicate that, in most instances, trout will not be greatly affected by grass carp, or by weed removal.

However, the lack of precise information shows the need to proceed with caution when considering weed removal in small or shallow lakes, which lack any cover other than weed beds (Rowe & Schipper 1995). The potential for serious effects on trout in large and deep lakes is less likely because in such waters trout can more readily avoid predators and are not as dependent on submerged vegetation as a food base. Rowe & Schipper (1995) generally made similar comments regarding most other fish and aquatic life. In North America, Chilton & Muoneke (1992) cited numerous examples of fish being adversely affected by the activities of grass carp, but conversely there were also examples of other species being enhanced.

Potential impacts on birds

No direct effects of grass carp on waterfowl have been reported. Indirect effects from weed removal are, however, likely to be significant. Rowe & Schipper (1995) reviewed the effects that grass carp might have on waterfowl in New Zealand. Ten species were listed to have been found with more than 50% of plant food in their diet. Black swans are probably totally herbivorous and will be more acutely affected. Displacement of black swans as a result of a high degree of weed control is likely to cause a movement of grazing pressure to other non-targeted vegetated sites and may have long-term ramifications (Clayton *et al.* 1998). Other waterfowl species such as mallard/grey duck, grey teal, shoveler, New Zealand scaup, coot, pukeko, paradise shelduck, Canada goose, and welcome swallow included aquatic vegetation and a range of weed bed fauna in their diet. In this way a change in vegetation abundance could affect invertebrate fauna available for wildfowl. No detailed studies of the impacts of grass carp on waterfowl have been undertaken in New Zealand, so, as for fish, the lack of precise information emphasises the need in sensitive areas to proceed with caution and monitor the effects. This approach is supported by overseas findings summarised by Chilton & Muoneke (1992) and Cassani (1996).

Potential impacts in the catchment

In many situations escaped fish will be at such low densities that the quantity of vegetation consumed will be insignificant on an area basis. However, a worst-case scenario is that each fish will survive and grow to >20 kg and their effects could be intensified by the fish moving in groups and selecting preferred species. The potential for cumulative impacts with multiple releases of grass carp was considered by Clayton *et al.* (1999). They concluded that there is potential in watersheds with large numbers of grass carp for escapees to eliminate certain aquatic plants in non-target areas. This may have a significant effect on weed-dependent species of waterfowl, invertebrates and fish. Cumulative impacts based upon movement of other grazers (such as swans) from grass carp release sites to non-target sites is also possible. Submerged plants, in shallow waterbodies already under stress, could be destroyed from added grazing pressure, potentially leading to a long-term decline in water clarity and non-recovery of submerged vegetation. Loss of submerged vegetation in non-target sites would result in a proportional decrease in populations of weed-dependent species.

2.2. DETERMINATION OF FLOOD RISK IN RELEASE AREA

If the release area connects to other waterways there is a chance that fish will escape. Flooding is one likely cause of this. Regional councils maintain historic records of rainfall and flood events. If sufficient data exist for the area in question, the likelihood of a given size of flood can be assessed. A consideration of the catchment size, its nature (with regard to the rate of runoff), the size of the channel or waterbody carrying capacity, and modelling a given rainfall event will also provide an assessment of potential flood levels.

Evidence based on historical attempts to contain grass carp within targeted sites suggests that future escapes are inevitable, either on account of unpredictable climatic events resulting in failure or damage to control structures, or from human error. This is particularly true for open or interconnected water systems that require construction of screens or fish barriers to confine the fish, rather than for land-locked waterbodies that have, understandably, never presented a significant risk of escape. The most significant and well known escape was of 1500 - 2500 diploid grass carp into the Waikato River from the AkaAka drains in 1984. This escape was due to the failure of screens to withstand the erosion forces of a flood event. A recent inspection of Lake Henley (Wellington Region), and the reported collection of a dead grass carp from Lake Wairarapa in the lower end of the catchment, suggest that an escape has occurred at this site too. Circumstantial evidence supports this, since the intake to this lake from the Ruamahanga River was not screened prior to either of two releases. This second case demonstrates a failure to prepare or comply with an appropriate operational plan for grass carp release.

2.3. APPROPRIATENESS OF A WATERBODY FOR FISH RELEASE

Grass carp can die from a variety of causes including low dissolved oxygen, acid pH, toxic substances, starvation and predation. Prior to preparing an RAR for release of grass carp, it would be advisable to establish that the area is suitable for fish in general and grass carp in particular.

The RAR should provide an inventory of the fish species present in the area of release. The presence of resident fish is a good indication that the area is suitable for grass carp. The presence of Galaxiidae, Retropinnidae (smelt), Eleotridae (bullies) and Anguillidae (eels) would indicate suitable conditions.

The presence of only short-lived species (inanga) or recent migrants (elvers), and the absence of older/larger fish, such as eels, could indicate the area is prone to periodic fish kills.

Low oxygen and pH (particularly in late summer), and pesticide contamination of water from adjacent land are factors which could kill grass carp. Oxygen and pH are relatively inexpensive to measure and are the most likely parameters to be problematic for fish survival in lowland drains. Oxygen levels are best checked early in the morning during summer. The use of adjacent land for horticulture would indicate that there is a risk of pesticide contamination and the absence of the indicator fish species could be an indication of contamination.

Seasonal temperature data for the waterbody concerned would also be useful. Temperatures above 15 - 17°C and not exceeding 30°C are usually required for grass carp feeding and effective weed control. Temperatures above 17°C for at least 3 months of the year are recommended (Cassani 1996). In a New Zealand trial they fed intensively (100% body weight per day) at 20 - 23°C (Edwards 1974).

3. Means of controlling aquatic weed infestations

Grass carp form the only effective biological control agent for submerged weed control in New Zealand. Submerged aquatic weeds can, however, be controlled by alternative methods including: chemical control using diquat (the only one registered for use in New Zealand); weed cutting (mechanical or manual), draglining (using a blade and a digger); habitat manipulation (e.g., water levels, water flows and shading, where these parameters can be manipulated), salt water intrusion; bottom lining; suction dredging (vacuuming up the weed, not the sediment); and rotovating (Clayton 1996).

3.1 CHEMICAL CONTROL

A number of chemicals are used overseas for the control of aquatic weeds, but in New Zealand the only one registered for use in water is diquat. Public perceptions of the use of diquat and other chemicals are generally adverse. Diquat is a water-soluble cation which is a contact herbicide. It has a long history of use in New Zealand (Clayton 1986) and has been used with considerable success for over 30 years in the Rotorua Lakes area. Diquat is relatively cheap, with chemical costs ranging from $300 to $1,400 per ha, depending on the species to be controlled.

Advantages

- Diquat is reasonably selective for target oxygen weeds such as *Elodea canadensis, Lagarosiphon major, Egeria densa* and *Ceratophyllum demersum* and it has little effect on non-nuisance native plant species, particularly charophytes.

- At herbicidal rates it is not known to be toxic to fish or most other aquatic life. For example diquat has been used in salmon hatcheries to control gill infections.

- Diquat is short-lived in natural waters, being strongly adsorbed by suspended organic matter and clay particles or plants.

- De-activated diquat has no residual toxicity and is degraded by microbial organisms.

- The acute oral toxicity for humans is conservatively estimated to be 50 mg kg^{-1}. An adult would need to drink 1500 litres of diquat-treated water at 2 mg l^{-1} to take in this quantity. Caffeine and nicotine are more toxic to humans than diquat is at herbicidal rates.

Disadvantages

- A consent is required and this can be costly if there are objectors.

- If the water is used for bathing, stock watering, drinking or irrigation, then alternative arrangements are required for 24 hours.

- Treated plants remain in the waterbody and rot in situ, requiring that a maximum of 25% of the total static waterbody be controlled at a time to avoid significant oxygen depletion.

- Diquat cay be ineffective in turbid water or when target plants are covered in periphyton or mud. Water movement will reduce contact times and may prevent the chemical from controlling the target species.

3.2 WEED CUTTING

Weed cutting can be by hand or using a mechanical weed cutter. Environment BoP operates a small weed cutting machine for c. \$325 ha^{-1} (based on a charge-out rate of \$65 hr^{-1}). This does not include the cost of weed removal (which can more than double the cost), or the cost of transoort of the weed-cutting boat to a site (\$150 day^{-1} for the truck, plus \$1 km^{-1}). Weed harvesting (cutting and removal) is usually priced around \$2,000 ha^{-1}. Weed cutting is able to target a specified area and cut to a required depth, though the maximum depth is usually around 2.0 m. Weed cutting can be likened to mowing the lawns and may have to be repeated twice in one growing season to achieve the desired level of control.

Advantages

- Weed cutting operations are usually supported by the public.
- Minimal environmental impact, as the margins of drains and canals can be left intact for habitat and bank stability.

Disadvantages

- Weed harvesting (cutting and removal) results in capture of a wide range of aquatic organisms (including many smaller fish, which hide in the weeds for refuge).
- Operating depths are often limiting.
- Weed harvesters are slow at clearing large areas and are hampered by wind or conditions which obscure the target weed from view of the operator.
- When the weed is to be removed from the waterbody, a suitable unloading point is required nearby and an area for dumping the weed is required.

3.3 DRAGLINING

This is a common form of weed control in drains in New Zealand. It can cost between $1,000 and $3,000 per km of drain (c. $5,000 ha^{-1}). It also removes the sediment from drains, which may be required even if aquatic weeds are not present. It is an effective means of maintaining an open waterway for drainage.

Advantages

- Draglining can be applied to selected areas, and a high level of weed control is achieved in a predictable way.

Disadvantages

- Draglining can over-deepen and over-widen drains.
- It also affects the margins of drains and can lead to bank instability and loss of marginal habitat.
- The areas for control are limited to those within reach of the machine.
- The aquatic habitat is greatly affected by sediment disturbance and total vegetation removal.
- Clearance may have to be repeated more than once a year where weed growth is rapid.

- Fish and other aquatic life caught in the bucket are injured or left to die on the spoil heaps.

- Dredged spoil needs to be dumped or is left in heaps on the banks.

3.4 ROTOVATING

Rotovating works on the principle of disrupting the sediment where nuisance weeds are rooted. Greater operating depths (4 m) can be achieved than with cutting. The method is commonly used in British Columbia to control *Myriophyllum spicatum* and can provide longer control than mechanical harvesting (Newroth & Soar 1986). This option has been developed and used under contract to Land Information New Zealand in Lake Dunstan. However, evaluation of this technique in New Zealand is still in its early stages.

3.5 SUCTION DREDGING

Diver-operated suction dredging techniques have been refined to suck up surface sediments and macrophytes with little disturbance of the substrate. Results in Lake Wanaka and Okataina have shown removal of nuisance weed species and replacement with native macrophytes (authors' unpublished data). Site-specific eradication of *Lemna major* has been achieved in Lake Wanaka using a suction dredge, by removing all vegetative portions of the plant. This technique costs about $7,000 ha^{-1} including removal and dumping. Re-colonisation of the area by native species occurs from seed or vegetative spread. Re-invasion by nuisance species can be slow depending on the area's proximity to a source of inoculum. In a trial in Lake Okataina, *L. major* weed beds were left within 10 m and re-invaded after two seasons. Pumping weed to > 18 m water depth causes it to sink and reduces operating costs markedly.

3.6 BOTTOM LINING

Bottom lining with weed mat or black plastic has been used to eradicate localised weed infestations and maintain areas weed-free. This technique has been used at boat ramps and jetties in Lake Rotoiti. It has been effective for long periods of time where deposition of sediment on top of the lining material is minimal. For example, bottom lining adjacent to one jetty in Lake Rotoiti on a moderately exposed site has kept the area weed-free for the past 20 years. Bottom lining has been also used to eradicate *Nymphoides geminata* from Lake Okareka and to eliminate *L. major* at some sites in Lake Wanaka (Clayton 1996).

The cost of bottom lining is c. $500 per 100 m^2 (50 000 ha^{-1}) which can be cost effective on an annual basis at suitable sites, where the results can last for several years.

3.7 HABITAT MANIPULATION

A wide range of habitat manipulations are possible depending on the site and the weed species targeted. Common examples of manipulations used in New Zealand are: change in water levels, water flows, shading, change in substrate (rock or concrete lining), and salt water intrusion. These manipulations are often site specific in terms of suitability, and their impacts may require careful consideration.

3.8 GRASS CARP

Advantages

- Can provide a high degree of submerged vegetation control at sites suitable for the fish.
- Can control a wide range of weed species including *Hydrilla*.
- Can be effective for a long period of time over large areas.
- Can be cost effective at c. $1,500 ha^{-1} for fish stocked at 60 fish per vegetated ha. This excludes costs for security, the RAR, and costs associated with the application for DOC approval.
- Weed eradication is possible. For example, *E. densa* was eradicated from Lake Parkinson and a native plant association established naturally after the fish were removed using rotenone (Rowe & Champion 1994; Tanner *et al.* 1990).

Disadvantages

- Management to produce low densities of weed has rarely been achieved.
- Fish re-capture is difficult and usually costly, although current trials in L. Waingata, Northland, using Prentox (rotenone-spiked food pellets) show promise.
- The fish can die from a variety of causes including low dissolved oxygen, acid flushes, and predation resulting in inadequate numbers for weed control.
- The fish require warm temperatures (>15 - 17°C) for active feeding, so control is restricted to areas where temperatures are suitable.
- Grasscarp prefer *Nitella* and *Chara* species (New Zealand's most common native macrophytes) to all target species. Low densities of grass carp may remove these species first, in the absence of other factors (such as temperature) affecting their feeding.
- Grass carp may migrate long distances if they escape.

3.9 INTEGRATED CONTROL

No one method of control is the appropriate solution for all weeds in all situations and often a combination of control methods may produce the best results. An informed choice of the appropriate option (or combination of options) requires an in-depth knowledge of the whole range of options and ways one option might enhance another. For example, in the 4.7 km Wheao Canal (3 m deep by 20 m wide), *Elodea canadensis* was reduced by using a low dose of diquat (20 litres total) followed by a high-flow operating regime to scour central portions of the canal. The high flows were only possible after the weed was treated. At the head of the canal a digger was also used to remove thick (>1 m) silt deposits. *E. canadensis* was left on the margins of the canal and this was achieved by partial lowering of water level at the time of treatment with diquat. This result was requested by Fish and Game to maintain habitat diversity and they considered it would be beneficial to the valued trout fishery.

4. Design of a monitoring programme for released fish

Once grass carp have been released into any given waterbody there are a number of parameters that should be monitored:

Aquatic vegetation control. The most obvious and readily monitored parameter is aquatic vegetation. A pre-release assessment of vegetation should be of sufficient detail to provide a meaningful baseline for updating changes in plant and species composition, density, and cover. The most appropriate methods and frequency for any vegetation survey method will depend on the nature of the waterbody, and in this respect it is recommended that the methods established for the pre-release assessment continue to be followed. Weed surveys using the methods described by Clayton (1983) as a guide, on an annual basis, would provide useful data on weed abundance. Records should be kept of the weed abundance at the release site and should be assessed prior to the introduction of grass carp to estimate fish numbers required, and whether a prior reduction in weed biomass (e.g. by chemical means) is necessary before grass carp introduction.

Records of observations of fish and their location would also be useful. If the fish are present at sufficient densities with suitable temperatures and water quality, then some weed control should become apparent after the first growing season.

Site integrity. Containment structures at any release site should continue to be monitored to ensure that no significant change in risk factors has taken place. Inspection of any containment structures should be carried out at the time of aquatic vegetation surveys and additional observations made after any exceptional climatic or disruptive event such as storms, floods, or ground movements. In the event of grass carp escaping, it would be appropriate to extend monitoring to include likely sites that could be impacted as identified in the RAR.

Water quality. Removal of aquatic macrophytes can be associated with increased turbidity of water, both from re-suspended bottom sediments and from increased phytoplankton. Any significant and sustainable reduction in water clarity due to development of algal blooms should be noted. In this respect it would be particularly helpful to have water quality records over a number of previous years so that meaningful comparisons can be made. Secchi disc depth provides a useful indicator of water transparency.

Fish populations. If significant communities of fish are identified in the proposed release site in the RAR, they should be monitored annually to detect major impacts and allow for the possibility of restoration before impacts are irreversible. Any fish kills (including grass carp) should be recorded and an attempt made to determine the cause of death.

Wildlife. Loss of marginal wetland vegetation around waterbodies due to grass carp can result in a reduction in nesting and resident bird life. Changes in significant resident bird populations should be noted, as for fish.

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