Cumulative impacts of multiple grass carp releases

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Summary

- We consider that a detailed review of the need for sterile grass carp (Triploids) in the lower Waikato River catchment or elsewhere is not warranted. Any increase in water temperatures and in flood events related to climate change may increase the risk of escape and potential spawning by grass carp. However, in the event of successful spawning, the lack of nursery habitats for prolarvae and entrainment potential would be critical factors mitigating against successful recruitment by this species. The global experience is that grass carp reproduction in rivers outside their natural range is both rare and precarious.

- There is potential in watersheds with large numbers of grass carp for escapees to eliminate aquatic plants in non-target areas. This would be expected to have a significant effect on weed-dependent species of waterfowl, invertebrates and fish.

- Cumulative impacts based upon movement of other grazers (e.g. swans) from grass carp release sites to non-target sites is possible. Submerged plants, in shallow waterbodies already under stress, could collapse 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.

- It is recommended that consideration be given to identifying exclusion zones on a catchment basis where there is a risk of grass carp escaping into sensitive or vulnerable habitats, or where indirect effects on neighbouring waterbodies are likely.

- Partial vegetation control has been rarely achieved using grass carp. A Risk Assessment Report for a waterbody targeted for control using grass carp should therefore consider the ramifications of long-term vegetation removal.

1. Background

Commercial availability of diploid grass carp *Ctenopharyngodon idella,* and an escalating number of applications for their release into a wide variety of waterbodies have raised concerns at the potential for cumulative impacts from multiple releases within a catchment. The Minister of Conservation approves or declines applications for release of grass carp under the Conservation Act. The Minister's decision is based on an assessment of the degree of risk of environmental impact occurring at the release site, or in other areas accessible to the fish if they escaped. These issues are required to be addressed within a Risk Assessment Report which must provide the information required by the Department of Conservation regional office staff to make recommendations to the Minister.

Concern has been expressed that the present policy and legislation governing the release and subsequent management of grass carp may be deficient. For example, cumulative impacts from multiple releases are presently not able to be considered. A similar analogy would be if, under the Resource Management Act, applications for waste discharged or water abstraction for a given waterbody were to be considered in isolation, without regard for the incremental impacts of multiple consents.

The Minister of Conservation has requested that urgent consideration be given to the potential for cumulative impacts to arise from multiple grass carp release sites. Given the nature of the questions surrounding this issue and the time frame within which answers have been sought, the scientific judgement provided within this report is unavoidably qualitative in nature. This report is therefore intended as a discussion document to further facilitate informed debate and to help identify whether a review of current policy and legislation on grass carp is required.

The discussion below addresses the following aspects of cumulative impact in decreasing order of commonly perceived risk:

- Could diploid grass carp reproduce naturally (only relevant for Waikato River)?
- Could escaped grass carp have significant undesirable impacts?
- Could grass carp cause other grazers to transfer their impact elsewhere?
- Could multiple grass carp sites degrade overall catchment values?

2. Could grass carp reproduce in the Waikato River?

The Waikato River represents the only waterbody within New Zealand where there is thought to be potential for feral grass carp to breed. Although this issue has been discussed in a previous report (Rowe & Schipper 1985) it is briefly reconsidered here, since there is now perhaps a greater potential for grass carp presence within this river and a greater recognition of the potential influence from changing climatic conditions, or the occurrence of extreme events such as the recent 100 year flood. The following discussion on the risks associated with the presence of grass carp considers firstly whether they are likely to spawn within the Waikato River and secondly whether any successful spawning would lead to the development of a naturalised breeding population.

2.1 RISK OF GRASS CARP SPAWNING

In order for grass carp to spawn successfully, diploid adult fish of both sexes would need to congregate in the vicinity of the Karapiro Dam tailrace, since this is where conditions suitable for spawning are known to occur. For this to happen, either grass carp would need to have been deliberately released into the Waikato River, or containment measures would need to be deficient, with the result that significant numbers of fish escape into the Waikato River. The risk of escapes is discussed elsewhere in this report.

If future global climatic change were to result in an increase in water temperature in the lower Waikato River and an increase in summer flows, then both of these factors would be expected to increase the chances of successful spawning by grass carp. For example, any increase in water flow would give rise to more turbulent water below the Karapiro Dam spillway, which in turn would create better conditions for spawning. However, there is a lack of data on the characteristics of flows eliciting spawning, so it is not clear just how likely such an event would be.

2.2 RISK OF GRASS CARP RECRUITMENT

A worst case scenario will be adopted here by assuming that there has been spawning of grass carp below the Karapiro Dam, and that eggs have been shed into the water and fertilised by the males.

Grass carp eggs are relatively large and semi-buoyant. Water movement is needed to prevent them from sinking and dying. Although eggs in rivers can be maintained in suspension for short distances (<5 km) by water velocities as low as 0.23 m/sec (Leslie et al. 1982), successful reproduction has only been known to occur where water velocities exceed 0.6 m/sec (Stanley et al. 1978). Leslie et al. (1982) indicated that, in very clear water, egg losses over 3.2 km were 99% at water velocities of 0.23 m/sec. This high loss was attributed to high levels of egg predation in clear water, but could also have been explained by eggs settling in zones of lower water velocity (e.g. pools). In turbid water it is possible that predation may be reduced and egg losses may not be as great. However, the role of predation versus egg settling is unresolved.

Two aspects of extreme floods are likely to hinder the chances of recruitment. Firstly, flood flows will increase the speed at which eggs are carried down-river, and this means that they will be carried further down-river before they hatch. Secondly, floods will result in a reduction in river water temperatures, and this will increase incubation times and delay hatching. At water velocities of 0.6 m/sec, eggs would travel down-river at 2.2 km/hr. However, during flood flows, such as the recent 1998 flood, or when flows exceed 500 cumecs, mean water velocities would exceed 1 m/sec and eggs would travel down-river at 3.6 km/hr.

The distance that eggs travel from spawning to hatching depends not only on water velocity but also on water temperature. At temperatures of **25°C** the minimum time to hatching is about 18 hours, whereas at 20°C it is over 34 hours (Rowe & Schipper 1985). During a summer flood event, when water velocities exceed 1 m/sec, eggs at 25°C would travel about 65 km down-river before hatching, whereas eggs at 20°C would travel 120 km. However, water temperatures of 25°C are unlikely to occur in the river during flood conditions, as the storm events responsible are generally associated with relatively low air temperatures and higher flows, both of which will reduce water temperatures.

The most important factor affecting the prospect of successful recruitment of grass carp larvae is the absence, or inaccessibility, of flood plains along the Waikato River suitable for early larval rearing. This was identified previously as the major factor limiting the chances for successful reproduction by grass carp in this river (Rowe & Schipper 1985). Flood plains provide essential habitat for the prolarval stage of grass carp. Prolarvae have limited mobility (essentially constrained to vertical movements) and are therefore vulnerable to passive transport down-river in currents. In most rivers where grass carp reproduce successfully, flood plains provide a large volume of still, shallow, warm water containing vegetative cover (inundated terrestrial plants). Prolarvae which are washed into such areas in flood flows can complete the larval stage of their life cycle in such habitats. However, if flood plains are not present, prolarvae will be carried on down-river by the current and transported out to sea, where they will perish. Thus, rivers where flood plains receive the bulk of flood flows can be expected to create optimal conditions for grass carp recruitment, whereas entrained rivers where flood plains are minimal, or lost, will provide inadequate habitat.

During a large summer flood event (resulting in water velocities over 1 m/sec and water temperatures below 25°C), eggs would be expected to travel over 65 km and possibly as far as 120 km down-river from Karapiro before hatching. The Rangiriri flood plain area is some 80 km below the Karapiro Dam. Eggs would hatch before the flood plain only if water temperatures were 25°C or higher, which would be unlikely during a storm event. They are more likely to be closer to 20°C and will only approach 25°C and higher when fine conditions prevail and flows are low. Most eggs would therefore pass the entrance to the flood channel before hatching, or even if they were to enter the flood plain they would settle out and die. The flood plain at Rangiriri is therefore too close to the potential spawning ground at Karapiro to provide a suitable nursery habitat during extreme flood events. During smaller floods, water would not enter the flood plain, so eggs or larvae would continue to be carried down-river and hatching larvae would be unlikely to find suitable nursery habitat before being swept out to sea.

Moreover, flood control works in the lower Waikato River now ensure that most flood waters are ducted out to sea, and floods large enough to over-top the river banks and spill into adjoining wetlands are now rare. However, extreme events, such as the 1998 flood, which resulted in water overflowing the bank across SH1 at Rangiriri, can be expected to be more frequent in the future, given accepted scenarios on climate change. Even so, this flood was not large enough to result in a large proportion of the flow being diverted out of the river course. As a result, few larvae would enter this flood plain area during such a flood. A much larger flood would be required to both create a suitable flood plain habitat, and to transport most prolarave into it. Thus, although global climate change and an increased frequency of flood events may enhance the probability of successful grass carp spawning, larval recruitment would not be enhanced by such flood events and we consider larval recruitment unlikely.

There are two further sources of information that help in evaluating the risk of grass carp spawning and recruitment in New Zealand. Firstly, since the escape of around 1500-2500 diploid grass carp into the Waikato River in 1984 there has been no evidence of spawning or successful recruitment. Secondly, though there have been reports of larvae and hence of grass carp spawning in the Mississippi and Illinois Rivers (USA), there has been no development of an established spawning population. Furthermore, although reproducing populations did develop from deliberately stocked fish in the Tone River (Japan) and Kara Kum Canal (Russia), these have since declined, indicating that even where breeding populations do establish successfully they are not easily sustained.

Since the initial New Zealand impact assessment on grass carp 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 overestimated.

Global experience indicates that successful reproduction by grass carp outside their natural range is extremely rare. Where it does occur, it is generally on a small scale and not sustained.

3. Could escaped grass carp have significant undesirable impacts?

The primary mechanism for cumulative impacts to arise from multiple grass carp releases derives firstly from their risk of escape (or illegal transfer) and secondly from their potential to congregate in sufficient numbers to exceed the vulnerability threshold of a given habitat or species of significant ecological value in a non-target area.

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 Aka Aka drains in 1984. This escape was due to the failure to erect screens able 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.

All known cases of escape and non-compliance with operational plans represent convincing evidence that further escapes and non-compliance will occur. Once a site has been approved for release of grass carp, Department of Conservation (in contrast to Ministry of Fisheries) has no existing statutory power to control the number or frequency of grass carp subsequently released to that site. For example, re-stocking of fish may occur repeatedly if the desired level of weed control is not achieved. This could lead to a build up of fish numbers over the years, with little accountability for whether the poor control may be arising from repeated escapes.

Perhaps one of the biggest risks is related to potential escapees from drainage channels. For instance, cumulative impacts might occur where escapees have access to interconnected wetlands and areas of ponded open water associated with the drainage system.

One example of an area at risk from multiple releases and potential for cumulative impacts is the Waikato Region. An increase in stocking sites in the Lower Waikato Region will inevitably increase the probability of escapes into the Waikato River. In general, the risk of escape will be increased by a higher frequency of severe flood events during summer months. Such events are associated with 'La Nina' type weather patterns and are predicted to increase as a consequence of global warming. The maximum number of grass carp that could potentially be released in the lower Waikato Basin would be around 500000 fish. This is based on the assumption that up to 3500 ha of drains and waterbodies could potentially be stocked (at 150 fish/ha) to control aquatic vegetation (including submerged and marginal weeds). Although the total area of waterbodies in the lower Waikato is c. 18 000 ha (Buston 1996), the area of non-targeted submerged vegetation in these same waterbodies is estimated to be around 2000 ha. Over 20 000 feral grass carp (cf. 1500-2500 escaped in 1984) would be required to potentially eliminate all of this vegetation, or around 4% of the maximum number of grass carp that could be potentially stocked in the region. It can therefore be concluded that there is some risk for escaped feral grass carp to eliminate weed beds in non-target areas associated with the Waikato River. This would have a significant effect on weed-dependent species of waterfowl, invertebrates, and fish.

Furthermore, there is perhaps some potential for a change in ecological values to occur as a result of low-density feeding by escapees on selected plant species, resulting in either a shift in species dominance or perhaps a decline in a rare species. However, such an impact would be difficult to reliably attribute directly or indirectly to grass carp, particularly where shifts in plant species dominance are an on-going phenomenon associated with competition (especially by invasive species) or where there is a history of changing water quality. Moreover, in the absence of monitoring, such vegetation shifts would probably escape notice.

Of most concern would be situations where grass carp escapees have the potential to access high-quality minimally impacted aquatic habitats containing predominantly native plant species. However, such waterbodies tend to occur in this state on account of their isolation, which in turn would often also protect them from risk of grass carp access. In such situations where there is a realistic risk of escape, an adequate risk assessment report should correctly identify these concerns and the application would be expected to be declined.

4. Could grass carp cause other grazers to transfer their impact elsewhere?

A potential cumulative impact could arise where de-vegetation occurs within a waterbody following grass carp release, which then leads to the movement of grazing pressure by other weed-dependent species such as waterfowl and coarse fish to other vulnerable, non-targeted vegetated sites. This applies to birds which can fly between waterbodies in their quest for food (e.g. grazing black swans) and to small coarse fish that may pass through screens erected to contain grass carp. Such effects were noted in the short term for black swans following the loss of macrophytes in Lakes Waikare and Whangape (Waikato), but were short-lived, as the population size later decreased proportionally to the reduced habitat available. However, there is potential for short-term increases in grazing pressure on neighbouring waterbodies to have long-term ramifications. This could apply to waterbodies where submerged plant growth is already under stress (e.g. from low water clarity), with the result that added grazing pressure could contribute to a collapse of submerged vegetation. Such a change in submerged vegetation status is typically associated with a further increase in water turbidity, which in turn continues to maintain the waterbody in a devegetated state (Blindow et al. 1993).

5. Could multiple grass carp sites degrade overall catchment values?

Could multiple releases of grass carp within approved sites be cumulative to the extent that they alter the overall character or balance of ecological values within a catchment? The issue here is whether or not any given catchment has sufficient waterbodies that are individually considered suitable for grass carp release, but where collectively the overall ecological values or character of the catchment could be compromised if multiple releases were approved. The analogy used to introduce this report was if, under the Resource Management Act, each request for a waste discharge or water abstraction was considered in isolation without regard for the incremental impacts of multiple consents.

The most tangible cumulative impact from multiple grass carp releases would be loss of vegetation sufficient to jeopardise its life-supporting capacity for other plant-dependent species (e.g. some waterfowl, coarse fish, and plant invertebrate fauna). In order for such an impact to be realised, it would be necessary for a significant proportion of waterbodies within a catchment to be suitable for control by means of grass carp. This scenario seems unlikely since it is common for waterbodies having a perceived aquatic weed problem to also have water quality conditions incompatible with grass carp survival, irrespective of whether or not approvals for release were granted. Periods of low dissolved oxygen are often associated with many weedy waterbodies, and pulses of acid water (from peat drainage) can render many waterbodies unsuitable for grass carp survival. Therefore in most cases it is likely that sufficient habitat will remain within any given catchment to support sustainable populations of plant affiliated species, without undue risk of cumulative impact from multiple grass carp releases. However, in some catchments where much of the residual habitat for waterfowl breeding is channelised and managed for flood control, high levels of weed control in spring would reduce waterfowl productivity while increasing drainage and reducing flood risk.

In conclusion, it is clearly difficult to predict with any degree of certainty what the direct or indirect cumulative impacts might be from increased use of grass carp for weed control. Any impacts will be density-dependent in terms of transferred influences (e.g. alternative biotic grazers) or direct impacts from grass carp escapees. Furthermore, it would depend upon the vulnerability of the non-target waterbody with respect to its propensity for change.

At this stage the experience with these matters is limited and it is therefore recommended that a conservative approach be adopted with respect to the use and release of grass carp in any catchment considered vulnerable to cumulative impacts. This might be achieved by identifying exclusion zones, and further consideration of this option is recommended.

6. General comment on use of grass carp

Artificially drained areas present a special case where it can be argued that the primary purpose and function for the existence of drains is to enable efficient removal of water from a catchment and to minimise flooding or damage to adjoining land. In such cases, the presence of abundant weeds (submerged or marginal life forms) impedes drainage and can present a flooding hazard. Furthermore, legislation empowers local authorities and drainage boards to remove, by the most efficient and economic means, any plant growth that is creating an obstruction to safe and efficient drainage.

However, water plants can provide a wide range of ecological benefits. For example, aquatic plants are important as a direct and an indirect source of food for a range of wildlife. They can also enhance biodiversity within a waterbody; and they provide a refuge for juvenile fish and zooplankton and an attachment substrate for invertebrates. Furthermore, they can help maintain water clarity by stabilising bottom sediments and by removing nutrients from the water column. Although an abundance of plant growth can be problematic to managers and other waterbody users, judgement is ideally required to balance the need for weed removal against the benefits provided by a weed presence, and such management is a growing trend in New Zealand and internationally. This judgement would be particularly relevant when grass carp are proposed for weed control.

Unlike other methods of weed control, where specific sites within a waterbody can be targeted for weed control, use of grass carp is renowned for resulting in total removal of aquatic vegetation within the whole waterbody. The practicality of achieving partial vegetation control in waterbodies by regulating grass carp stocking density is still unresolved. A trial has been proposed on partial vegetation control in Lake Omapere (Northland) and this would provide an opportunity to test whether such an objective can be achieved in New Zealand. However, any risk assessment report for an individual waterbody should still consider the consequences and acceptability of total vegetation removal from that waterbody.

7. Further issues

Further consideration is required on responsibility for on-going security of grass carp once they are released, on ensuring compliance with operational plans, and on what measures can or should be taken to mitigate against any damages arising from mismanagement.

Many applications for the use of grass carp now state that partial vegetation removal is the targeted outcome. There is, as yet, insufficient evidence for grass carp being able to achieve partial vegetation control as opposed to total removal in New Zealand. USA studies have demonstrated partial control for some lakes lasting 5-7 years, but partial control in the longer term is still uncertain. All applications for the release of grass carp on the basis of partial control should therefore be for experimental trials only and the areas carefully selected on the assumption that total vegetation removal is a likely outcome.

Inadequate provisions exist in the present policy and legislation relating to applications for release of grass carp to ensure that appropriate consideration is given to alternative weed control options. This is particularly relevant to managers that prefer (or in many instances should be required) to maintain some degree of vegetation presence in order to preserve habitat diversity. Given that it is not yet known whether grass carp are a reliable means of achieving partial or targeted vegetation control, it is considered inappropriate that, under the current legislation, managers are entitled to seek permission to use grass carp without presenting evidence on whether or not alternative control options may be better suited, or whether the desired level of control may be achieved without requiring total vegetation removal. It is recommended that consideration be given to integrating grass carp approval procedures with regional planning, where it would be possible to establish potential exclusion zones based on risks from cumulative impacts and to determine the nature and degree of vegetation control appropriate for waterbodies within the region.

Applications for release of grass carp to any specific waterbody should be graded according to risk and treated accordingly. For example, applications for isolated farm ponds without risk of escapes could be treated differently from applications for multi-use lakes or wetlands.

Statutory control over the approval and subsequent releases of grass carp is split between Department of Conservation and Ministry of Fisheries, which can give rise to difficulties. Applications could be better considered either by a specialised review committee with appropriate co-opted expertise as required; or by having applications heard through the Resource Management Act type of procedure. Either way, it is recommended that the final decision-making framework should be based on the following criteria:

1. Is aquatic weed control appropriate? (This should link to Regional Plan).

2. If control is appropriate, what options will achieve the degree of control required with least ecological impact or risk to the environment at affordable cost.

3. If grass carp are considered the most appropriate option, then decision-making should be structured according to the scale of risk and the size of release.

4. Operational plans should be vetted and incorporated into permits. The maximum number of grass carp for release should be stated, as potential impacts are density-related. Operational plans should also be reviewed and revisable by a controlling authority if the need arises.

Silver carp have not been researched sufficiently to be recommended for management purposes such as algal control. It is not considered appropriate for silver carp to be recommended as a complementary biological control agent to that of grass carp for two reasons; firstly there is insufficient evidence that silver carp are effective in being able to achieve sustainable control of algae, and secondly, the use of grass carp is rarely associated with increased algal problems requiring preventative algal control measures to be introduced. Any release or use of silver carp should be considered experimental, and appropriate trials should be established for their further evaluation.

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