Aquatic weed status and management options for Lake Kohangatera: 2013

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Cover: Diver examines egeria plants in open water area in the Gollans Wetland *(Photo: Aleki Taumoepeau, NIWA).*

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Executive summary

Greater Wellington Regional Council (GWRC) contracted NIWA to reassess the extent and performance of two aquatic weeds within the lower catchment of Lake Kohangatera, two years after the discovery of their initial incursions. Based on this assessment, NIWA identified the current threat from each weed, outline management options, and recommend a course of action.

The distribution, size of infestation areas and performance of elodea (*Elodea canadensis*) and egeria (*Egeria densa*) were investigated in Lake Kohangatera and in the three open water areas in Gollans Wetland in March 2013.

The distribution, depth range and cover of elodea in Lake Kohangatera and the Gollans Wetland had not changed substantially since first documented in 2011. It continued to be sparsely distributed (average covers ≤5%) along the northern and western shoreline of the lake. Patches of higher cover were present at the north-western sector. Extremely sparse and stunted plants were seen in the central lake area. Elodea remained in the open water areas in the Gollans Wetland as patchy covers (overall ≤5%).

The lack of change in status of elodea after two years, together with GWRC observations that it is widespread in the upper catchment within the Gollans Stream, leads us to conclude it has been present in the system for a number of years. Therefore, it is unlikely elodea holds further significant risk for biodiversity values of Lake Kohangatera under the current lake conditions.

Egeria was only present in the original site, an open water area of the Gollans Wetland, but had expanded since 2011 to occupy most of the open water area as high cover beds. Egeria was not found in the downstream areas of open water, or in the lake, nor did GWRC surveillance detect it in the upper stream. We conclude that egeria is a relatively recent introduction to this site in Gollans Wetland.

A review of salinity tolerances for egeria suggest that current salinity conditions in Lake Kohangatera will not constitute a barrier to weed establishment. High water levels and rainfall driven flow events may be sufficient to transport egeria past the current wetland filter downstream of the infestation. It is concluded that egeria poses a significant threat to the ecological values of this nationally significant lake.

Four potential options to manage, contain and/or remove the egeria weed risk were identified; the herbicide diquat, grass carp, artificial shading, and bottom lining. Grass carp is the only option considered likely to achieve egeria eradication in the open water area of Gollans Wetland. If this option is pursued we suggest that small numbers of large, older fish are stocked, which would not impact on the lake and wetland environment in the event of escape. If use of grass carp were considered unacceptable, the other options should contribute to an integrated management programme to contain egeria and seek to reduce the risk of downstream spread.

1 Introduction

Lake Kohangatera is one of the two Parangarahu Lakes located within the Wellington region. In 2011, Greater Wellington Regional Council (GWRC) contracted NIWA to undertake an ecological assessment of the Parangarahu Lakes. These assessments confirmed an excellent ecological status for Lake Kohangatera and highlighted nationally outstanding botanical values (de Winton et al. 2011, 2013).

However, at the same time, threats to the ecosystem of Lake Kohangatera were identified in the form of a new record for the exotic weed elodea (*Elodea canadensis*) and the discovery of egeria (*Egeria densa*) in an open water area in the wetland upstream in the lake catchment (Wells et al. 2011). GWRC have since established the widespread presence of elodea in the main stream draining the upper catchment, but no egeria was recorded in the checked area (Appendix A; Wayne Cowan, Senior Biosecurity Officer, GWRC, e-mail May 2012).

Recommendations from NIWA's 2011 reports included a re-assessment of weed extent and impacts for Lake Kohangatera after two years (de Winton et al. 2011, Wells et al. 2011). The purpose of this was to establish the performance of elodea under lake conditions, particularly if it proved to be a recent introduction to the lake, and to clarify the threat this weed poses to the botanical values of the lake. Concurrently, a repeated weed delimitation survey of the lake and three open water areas of the Gollans Wetland was recommended to establish the current status of egeria and detect if fragments have already entered the lake and established.

This report presents the results from a 2013 weed surveillance in Lake Kohangatera and the Gollans Wetland. Status of elodea is updated and future risk to the lake re-considered in light of findings, and the results of the survey in the upper catchment by GWRC. Delimitation of egeria distribution is considered and the information used to clarify the need for, and possible actions to manage, contain and/or remove this weed risk.

This surveillance investigation was undertaken in conjunction with a LakeSPI (Submerged Plant Indicators) assessment for Lake Kohangatera. The results from the LakeSPI survey are reported separately in de Winton (2013).

2 Surveillance and delimitation methods

The distribution, size of infestation areas and performance of elodea and egeria was investigated in Lake Kohangatera and in the three open water areas of Gollans Wetland on the 20th and 21st March 2013. The catchment in private ownership was not accessed, however, we take into account the reported surveillance for these weeds by GWRC that was undertaken in the upper catchment (Appendix A; Wayne Cowan, Senior Biosecurity Officer, GWRC, e-mail May 2012).

Areas in Lake Kohangatera were prioritised for weed surveillance based on known elodea distribution as a potential source of spread, wind/current directions and habitat availability. A combination of snorkel and scuba diving, snorkel tows and surface observations were used to document the location, depth range and size, cover and height of colonies. Areas searched in Lake Kohangatera were mapped (Figure 1) by GPS tracking (Garmin GPS unit), and divers paths taken in the open water areas of the Gollans Wetland were estimated (Figure 2).

3 Results

3.1.1 Elodea

In Lake Kohangatera, the distribution, depth range and cover of elodea was similar to that documented in 2011.

Previously, in 2011 elodea was described from the lake as low cover growths (<5% average cover) within a 2-3 m wide band immediately outside of the raupō (*Typha orientalis*) beds around the northern and western shore line (Wells et al. 2011). These elodea growths comprised individual plants and small clumps. No elodea was found in the backwater areas inside of the deeper reed beds, nor was it recorded in the central lake area (Wells et al. 2011).

Two years later in March 2013, diver tows around a similar search area to 2011 (Figure 1) showed elodea continued to be sparsely distributed (average covers ≤5%) along the shoreline, with one limited area of 2 m x 20 m at the north-western shoreline where maximum covers exceeded 50%. Spot dives at 5 sites described elodea at the north-western shoreline, where it contributed to vegetation forming a band on the outside of the emergent beds in 1.5 to 1.6 m depth, usually at ≤5% cover, but with some elodea patches up to 25% cover and 0.6 m in height. Isolated elodea plants were seen adjacent to two sites at the north-eastern and south-eastern shoreline, but none were seen at sites checked at the southern and south-eastern shores of Lake Kohangatera (Figure 1). Small (<0.1 m tall), stunted elodea plants were detected in some plant material retrieved from the central area of the lake, but these were extremely sparse.

In 2011 elodea was recorded in the Gollans Stream and all three areas of open water that were searched in the Gollans Wetland had widespread elodea at low covers of ≤5% (Wells et al. 2011). In 2013, elodea was present in all the open water areas in the Gollans Wetland (Figure 2), generally at patchy covers (overall ≤5%), although some higher cover beds existed towards the head of the lower pool.

Figure 1: Route of surveillance (GPS track as blue line) for elodea and egeria in Lake Kohangatera, indicating the observed distribution of elodea as yellow dotted line and most abundant area as yellow line.

3.1.2 Egeria

Egeria was first recorded in the catchment of Lake Kohangatera in 2011, when it was detected in the upper of three larger open water areas of Gollans Wetland (Wells et al. 2011). At this time egeria formed covers of c. 70% within a 2 m-wide band adjacent to the raupō at the edge of the open water, with isolated shoots scattered across the centre of the open water area (Wells et al. 2011). Despite intensive searching downstream and in the northern end of the lake, no further egeria was located in 2011.

In 2013 egeria was again only recorded from the upper open-water area in the Gollans Wetland (Figure 2), but its abundance had increased markedly. Egeria dominated the entire open water area (>90% average cover), with surface reaching beds extending around the margin of the open water area (Figure 3), and a subsurface canopy across the middle of the open area extending to the surface in places (Figure 4). Other submerged plant species included low covers of elodea, small beds of native pondweed (*Potamogeton ochreatus*) and milfoil (*Myriophyllum triphyllum*) as well as patches of charophytes (*Chara australis* and *Nitella* species aff. *cristata*). The open water area was fringed by raupō, purei (*Carex secta*) and toetoe (*Austroderia toetoe*.).

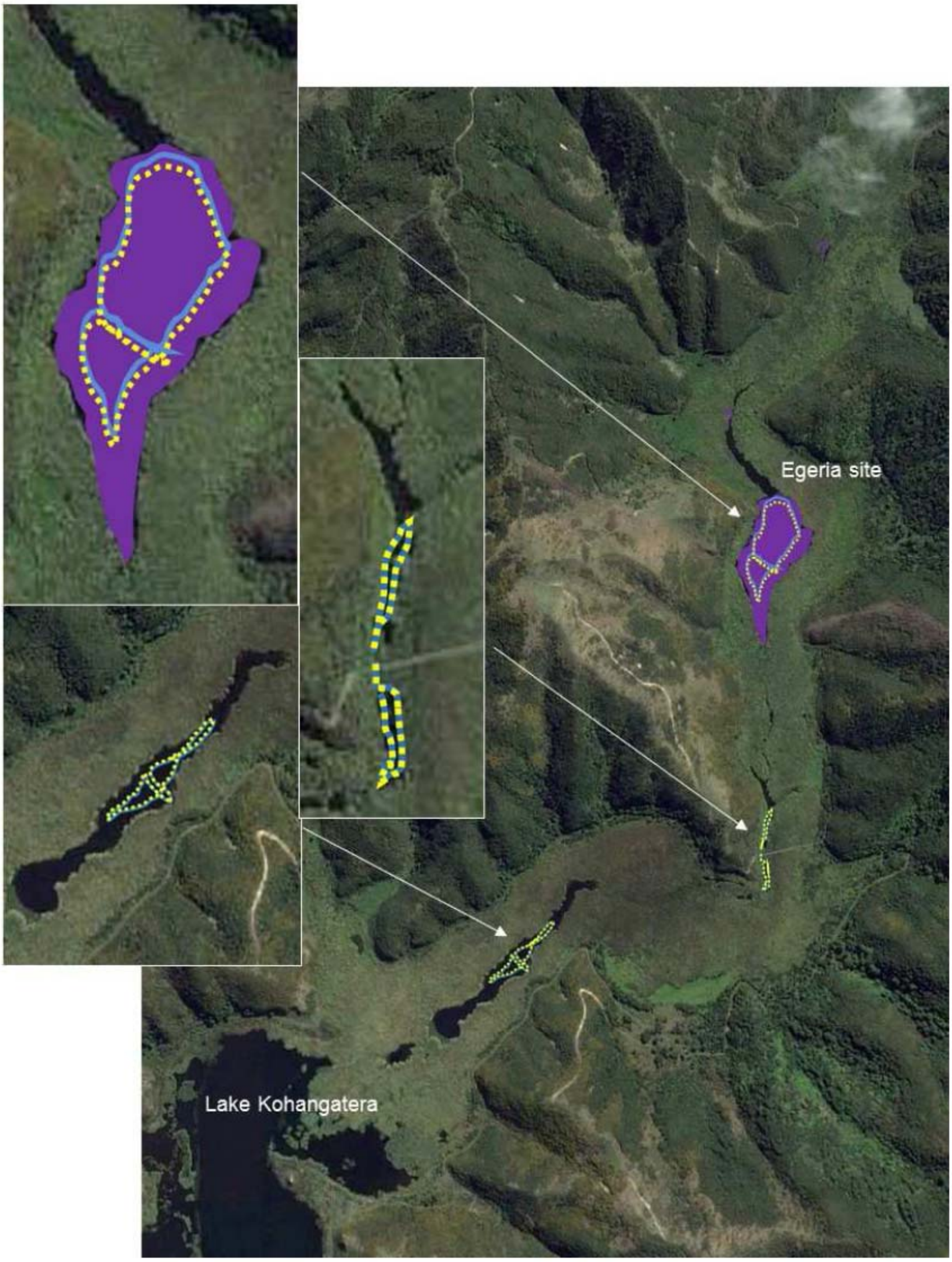

Figure 2: Estimated route of surveillance (blue line) for elodea and egeria in the Gollans Wetland. Observed distribution of elodea in yellow and area of egeria infestation in magenta.

Figure 3: Photo-montage of the upper open water area of the Gollans Wetland, showing the water surface with patches of surface reaching weed (red colour from trapped floating plants of *Azolla filiculoides*).

Figure 4: Photo-montage of the vegetation in the upper open water area of the Gollans Wetland, showing a diver with handful of surface-reaching, flowering egeria, and a submerged bed of egeria in centre of open pond, with native pondweed at lower left (arrow).

4 Discussion

The lack of change in status of elodea over the two years since it was first detected in Lake Kohangatera in 2011 confirms that it is unlikely to have a major impact in this system under current conditions. This conclusion is supported by the observation of widespread elodea presence in the upper catchment (Appendix A; Wayne Cowan, Senior Biosecurity Officer, GWRC, e-mail May 2012) that suggests it has been present in the system for some considerable time prior to the 2011 NIWA survey.

In contrast, the rapid expansion of egeria within the upper open water area of Gollans Wetland since first detected in 2011, together with its current restricted distribution, suggests it is a recent introduction to the system. In this open water area, egeria clearly demonstrates the ability to dominate this predominantly freshwater vegetation, although its performance within the higher conductivity/salinity conditions of Lake Kohangatera is unproven.

Salinity measurements in Lake Kohangatera in 2013 were similar throughout the main body of the lake at 0.39 to 0.41 practical salinity units (PSU used hereafter). Salinity was greatest at 0.43 PSU at the outflow culvert and lowest at 0.14 PSU close to the inflow from the Gollans Stream at the north-eastern shore. In 2006, salinity (conductivities of 368 to 788 µS/cm converted using a spreadsheet based on Fofonoff and Millard 1983) was c. 0.48 PSU at the southern shore, declined across a profile to 0.40 PSU at 60 m from the northern shore, with 0.22 PSU measured at the shore (Nicholson 2008). A maximum salinity of c. 0.59 PSU (conductivity 954 µS/cm) was recorded in the main body of the lake in 2011.

In the literature, maximum salinity tolerances for egeria are reported as between 5.0 and 8.0 PSU (Hauenstein and Ramirez 1986). Elsewhere, experimental studies revealed that both root formation and growth of egeria decline with increasing salinity, however, even at a salinity of 6, the plant shoots continued to grow, with an average growth increment of 10% to 40% over 18 days, depending on temperature (Obrebski and Booth 2003, reported by Gartrell 2010). This information led to the conclusion that manipulating salinity levels to control egeria in the Sacramento-San Joaquin Delta and Upper San Francisco Bay, USA, was not feasible (Gartrell 2010).

Salinity tolerances for egeria therefore appear to exceed the salinity conditions recorded in Lake Kohangatera so conditions will not pose a barrier to the establishment of egeria here. In freshwater systems, such as in the upper open water of Gollans Wetland, egeria can exclude most other submerged plants and is capable of surface-reaching growths from the maximum depth of Lake Kohangatera (2.2 m). Therefore, egeria should be regarded as a significant threat to the ecology and utility of the wetland and Lake Kohangatera.

The level of Lake Kohangatera naturally varies by more than 1.2 m (http://graphs.gw.govt.nz/lake-kohangatera-2/), although how this translates to water level variation, and the potential for flood releases from the Gollans Wetland area, is unclear. For egeria to be transported downstream would likely require that the current raupō barrier is overtopped or eroded by high water levels and high velocity flows.

5 Egeria management options

Potential options to manage, contain and/or remove the egeria weed risk are considered in the following sections 5.1 to 5.4. A brief background is provided on each option, the likely outcome of applying the option is considered, the ease or difficulty of application is identified, and aspects of implementation at the site are provided in the event the option is preferred. This information is provided as background to a recommended course of action which is outlined in section 6.

5.1 Diquat herbicide

5.1.1 Background

Diquat (active ingredient diquat dibromide) is the only herbicide registered for use within natural waters that would be effective against egeria, although it is unlikely to kill egeria as it is not usually active against root crowns present in the sediments. This herbicide has a long history of use in NZ (over 50 years) and at herbicidal concentrations diquat has very low risk to humans and non-target aquatic biota (Clayton and Severne 2006).

Diquat is a fast-acting contact herbicide that has minimal translocation within plants. It interrupts the electron transport system in photosynthesis, resulting in the formation of hydrogen peroxide which then desiccates green plant tissue. However, submerged plants vary widely in their susceptibility to the action of diquat. Diquat is rapidly absorbed by plants and both inorganic and organic compounds within the water and bottom sediments. This means diquat is present in the water column only for a short timeframe (minutes to hours). Adsorbed diquat has no residual toxicity, is not biologically active and is degraded by microbial organisms within sediments. For instance, no accumulation of diquat has been detected in sediment at sites that were regularly treated for decades (HortResearch 2001).

5.1.2 Expected outcome

Application of diquat to the upper open water area in the Gollans Wetland is expected to significantly reduce the biomass and height of the egeria weed bed. However, it is unlikely to eradicate egeria. Herbicide effectiveness would be reduced under large, diluting, water flows. However the clear water, negligible water movement, and the clean plant surfaces and the density of vegetation observed in this area in 2013 suggest a good control outcome will be possible; e.g., the suppression of surface reaching growths for at least one season and for up to a year. Herbicide efficacy would be reduced by turbid water inflows or silt deposits on plants if they occurred at the time of treatment because these preferentially bind diquat (Hofstra et al. 2001).

Length of egeria control may also be extended by the fact that native plant species are either unaffected by diquat at herbicidal rates (emergent plants, charophytes) or little affected (pondweeds, milfoils) compared to egeria. Therefore, suppression of egeria regrowth by expanding native submerged plants is possible.

5.1.3 Practical considerations

A resource consent will be required for the application of diquat unless it is a “permitted activity” in the region. Public notification would be required if the treatment area is considered accessible to the public.

Diquat in its undiluted form is a Class 3 poison and is therefore a hazardous substance. It should only be handled and applied by a registered chemical applicator according to label guidelines. While application of small amounts of aqueous diquat formulations (e.g., Reglone®) can be made to the surface water by hand sprayer from a small water craft, boat boom or helicopter application are more suitable for large areas. Precautions should be taken to ensure helicopter placement accuracy and reduce the risk of drift and over spray.

Aqueous formulations (e.g., Reglone®) contain 20% diquat dibromide, and a target concentration of 1 mg diquat dibromide per litre is sought to control weeds (i.e., a 100,000 × dilution). The New Zealand product label for Reglone® states the maximum application rate of 30 litres per ha, regardless of water depth. A water depth greater than 0.5 m would act to dilute applied diquat to <1 mg per litre (Clayton and Severne 2006), however, weed control has been achieved with application through several metres of depth of water. Herbicide efficacy depends upon the contact time achieved for an efficacious concentration of the herbicide in the weed bed. Therefore diquat is not so effective in situations where flowing water dilutes the herbicide and reduces the contact time. Water flow was not perceptible in the open part of the Gollans Wetland site, but is likely to be greater in the narrow upper system which receives inflows from the catchment.

According to the label, diquat application should be restricted to 25% of the total water surface during each treatment. Nevertheless, mixing and dilution result in treatment of a much greater area than the application zone. The 25% label recommendation is to reduce the risk of decaying plants lowering dissolved oxygen levels where there is a high weed biomass to water volume ratio. Risk for the open water area within Gollans Wetland can be further reduced by timing applications when water temperatures are low. However, it should be noted that low dissolved oxygen levels also occur in dense weed beds overnight, and so treatment may ultimately increase dissolved oxygen levels in systems (Clayton and Severne 2006).

Product and application costs are approximately $1600 per hectare when applied as per the label recommendations, plus application (e.g., helicopter) costs if applicable.

5.1.4 Possible implementation

- Diquat could be considered immediately as a method to reduce biomass and height of egeria, and hence risk of fragment generation for potential downstream spread to Lake Kohangatera. Diquat might also be utilised as a one-off treatment prior to other options, e.g., grass carp.
- We estimate the open water area of the Gollans Wetland at between 1.2 to 1.9 ha and the total area of Gollans Wetland is approximately 51 ha (not including the body of Lake Kohangatera), so the treatment area would be approximately 4% of the waterbody, therefore much less than the label requirement of Reglone® to treat less than 25% of the area of the waterbody. Hence, at the label requirement for Reglone® of 30 litres of diquat per ha, between 36 and 57 litres of product should be applied in any one application.
- Costs would be at least $1,600 per treatment but with extra costs relating to the inaccessible site or for helicopter application.

- Diquat effectiveness may be reduced under flowing water conditions (e.g., upstream area), due to dilution and a reduction in the time that a target plant is exposed to an effective herbicide concentration. Application should be made to maximise concentration-contact times in these areas. Diquat dispersion will result in a more widespread herbicidal action than just in areas of application.
- A pre- (e.g., by the applicator) and 6-8 week post-application assessment of weed abundance should be made to identify the level of control achieved.
- Timing of application is best in cooler months, with autumn being preferential, when weed biomass is maximal, and because winter flow events are seen as the greatest risk for downstream transportation.
- Consideration should be given to a two-phase treatment, where a second diquat application targets egeria re-growth following initial herbicidal effects, e.g., 2-3 months later.

5.2 Grass carp

5.2.1 Background

Grass carp (*Ctenopharyngodon idella*) were introduced to, and are artificially bred in NZ for submerged vegetation control (Rowe and Schipper 1985; Rowe and Hill 1989). Provided grass carp were stocked at a sufficient density for the vegetated area, they are likely to eradicate egeria from the open water area of Gollans Wetland. However, an assessment of the suitability of this control option would need to consider risks, including the feasibility of containing fish within the treatment area, and the ecological benefits of egeria eradication versus possible impacts from long-term de-vegetation of the open water area.

5.2.2 Expected outcome

Grass carp are non-selective grazers (Dibble and Kovalenko 2009), and are likely to consume all submerged vegetation in the open water area, as well as palatable emergent plants in water depths that allow fish access. The floating plants present in the open water area (*Lemna* and *Azolla*) are unlikely to be grazed (Rowe and Schipper 1985).

Total vegetation control (removal of all submerged vegetation) is possible within two summers at sufficient stocking rates. Active grass carp feeding occurs above water temperatures >15–17°C and they are known to feed intensively at 20–23°C, consuming 100% of their body weight per day (Rowe and Schipper 1985).

A de-vegetated state would be maintained for the length of time that sufficient fish grazing pressure is maintained. Fish would need to be recaptured or will persist for at least 20 years (see practical considerations). Even when all aquatic vegetation is removed, fish can survive in a system by consuming fallen leaves, marginal plants and epiphytic algae (NIWA data).

5.2.3 Practical considerations

Grass carp use is subject to approval from Department of Conservation (DOC) and Ministry for Primary Industries. Central to approval would be consultation with iwi, and other relevant and affected parties (regional Fish and Game Councils, adjacent landowner, recreational groups etc.). An assessment of the risks is required in the form of an Assessment of

Environmental Effects report. An Operational Plan is also required to determine containment, monitoring and long-term fish management requirements. Guidelines on the application process and application forms are available from DOC permissions staff or can be provided by the grass carp supplier.

A major consideration would be containment of the fish within the treatment area. The extensive beds of raupō within the inflow and outlet area of the Gollans Wetland site are unlikely to provide a sufficient barrier to fish movement in the long term, particularly as fish are known to browse this species. Grass carp are notorious at escaping as they have strong migratory instincts. Therefore, inlets and outlets need to be secured with nets, or screens usually constructed from metal bars (Hofstra 2011) and designed for the size of the fish. Nets or screens in flowing systems such as in Gollans Wetland would need to cope with flood flows and be maintained to avoid debris build-up and possible breaches or damage. Maintenance would be logistically difficult in this inaccessible site, although a screen installed at the downstream boardwalk area is a possibility. There may be a requirement to provide passage for native fish such as eels, which may be avoided if large grass carp were used (enabling a large mesh/screen size).

Grass carp escape would mean grazing was no longer concentrated in the target area and this may compromise egeria eradication. In the worst case scenario, if all the grass carp escaped, then they would be unlikely to have impacts within the larger lake and wetland complex because of the large vegetated area.

Effects of grass carp grazing of vegetation on water quality are poorly understood (Dibble and Kovalenko 2009), but the small size of the Gollans Wetland open water area, the buffer provided by extensive wetland vegetation elsewhere in the system, and the likely degree of flushing from the upper catchment means the risk of water quality deterioration is probably limited. Likewise, although ecological impacts on other biota are possible, mainly indirectly through the removal of vegetation, these would be spatially limited within the system. The greatest risk may be to fish passage, depending on the necessary screen configuration.

Overall costs for grass carp stocking is difficult to estimate due to the need for approvals and required consultation. The supply of fish from suppliers (B. Jamieson, NZ Waterways Restoration Ltd, 2013, pers comm.) is quoted for natural water bodies, at $40 each, plus live transport ($1.80/km), plus medication ($73/vat).

Re-capture or *in situ* euthanasia of grass carp when vegetation control aims are achieved is challenging, especially in large, or deep systems, and may be costly. Removal options include netting or traps, piscicides (rotenone or antimycin) in bait form (Rowe 1999) or whole-of-waterbody application of a piscicide (cube root powder/rotenone) (Rowe and Champion 1994), or combinations of these.

5.2.4 Possible implementation

- An application of diquat to reduce the biomass of egeria immediately prior to grass carp stocking would minimise the number of fish required. If vegetation biomass is reduced, a lower density of fish than the recommended 50 to 150 fish per vegetated ha should still exert ‘total control’.

- A large size of stocked fish (i.e., 5 to 10 kg) would be easier to contain, have a more limited remaining lifespan, and graze large amounts per fish. The pond has steep edges and access to shallow areas by smaller sized fish would not appear to be required.
- Screening for fish retention should consider a floating boom and net at the outlet from the open water area, and a screen (e.g. metal bars) constructed at the downstream boardwalk. Bar widths to retain the size of >5 kg fish would be c. 70 mm (required size should be checked against stock). Passage for large longfin eel that may not gain access through screens or nets should be provided at both fish barriers (e.g., sinuous submerged tube design).
- A low fish stocking density (e.g., 20 fish) should be used initially, with a review of vegetation changes after 1 year, and additional stocking if required.
- Stocking should be planned for spring to maximise grazing over the subsequent warm summer period.
- Monitoring of vegetation abundance and egeria presence should be undertaken on at least an annual basis.
- Egeria absence should be confirmed for a number of years (3 to 5 years) before eradication is confirmed. Therefore grass carp stocking should be planned for a minimum of 5 to 7 years.

5.3 Artificial shading

5.3.1 Background

Shading can control submerged weeds by limiting the amount of light available for growth. For the eradication of submerged weeds, surface covers that filter out 90% or more of ambient light need to be deployed over all, or at least large areas, of the water surface for a considerable time (probably >6 months). If insufficient coverage is achieved, light may allow plant survival at the edges of the treatment area.

Weed matting, suspended above the water surface has been used to control lagarosiphon in a Takaka stream by the Tasman District council and in a stream near Blenheim by the Marlborough District Council. However these are relatively small areas compared with the logistics of the 1.9 ha open water area of Gollans Wetland.

5.3.2 Expected outcome

The feasibility of covering such a large system as the Gollans Wetland open water area (estimated as 1.2 to 1.9 ha) in order to achieve egeria eradication is questionable. However, deployment of surface covers may have application in limited areas (e.g., the narrow inflow area where diquat concentration-contact time might not be achieved).

5.3.3 Practical considerations

Surface covers may be constructed from polyethylene, PVC, polypropylene, nylon, synthetic rubber materials or fibre glass screens. Constructed floating rafts of surface covers are advantageous in that they have little effect on water flows, and they can be moved around. Disadvantages are that storm flows and strong winds may dislodge them from the deployment area. Surface covers are easier to deploy over channels or narrow waterways. Surface covers are difficult to apply over obstructions such as clumps of wetland plants or fallen trees. Some materials may also degrade with sunlight.

In theory, control of plants could be achieved by sequentially treating sections of a larger system, starting at the inflowing end. In reality, egeria fragments may redistribute widely within the open water area with eddy flows, making this an unsuitable option for eradication.

Costs for shade cloth and materials for floating covers would vary greatly depending on design and construction, but a rough estimate is \$3 m^2 excluding deployment costs.

5.3.4 Possible implementation

- Shade covers should be established in early spring, at the start of the growth season.
- In an inaccessible site like the open water area of Gollans Wetland, floating sections of shade covers could be pre-fabricated and transported to the site by helicopter for final deployment.
- A robust anchorage system would be needed for any shade cover rafts.
- Regular checks would need to be made to ensure covers remain in place and un-damaged. Additional effort and costs would also be required in the event that a cover needs to be removed or re-instated.

5.4 Bottom lining

5.4.1 Background

Eradication of small areas of submerged weeds is possible using ‘benthic barriers’ to exclude the light required for submerged plant growth and to remove plant access to substrates for rooting.

The greatest limitation to the use of this option for egeria eradication in Gollans Wetland would be the difficulty of installation in this inaccessible site, and the feasibility of treating such a large area (estimated as 1.2 to 1.9 ha). Elsewhere, the upper feasible size for installation is suggested to be 0.4 ha (U.S. Army Corps of Engineers 2012). For instance, to ensure all egeria has been covered and fragments have not been able to re-establish on top of the linings would require a visual check of the entire covered area by divers. It is unlikely this level of accurate observation could be achieved.

However, bottom lining may have application in limited areas (e.g., the narrow inflow area where diquat concentration-contact time might not be achieved).

Varied materials are used for benthic barriers (Caffrey et al. 2010), such as woven weed cloth and biodegradable materials (‘hessian’ or coconut fibre matting) as considered below. As these are gas and water permeable they have advantages for installation and reduce the risk of liners being dislodged by the build-up of gas from organic sediments beneath.

5.4.2 Expected outcome

Bottom lining alone for the purpose of eradicating egeria in the Gollans wetland is impractical (unachievable and costly). However, egeria biomass would be at least temporarily reduced in areas where achievable bottom lining coverage is possible. For instance, bottom lining was the main option used to control lagarosiphon in Rosie Bay, Lake Waikaremoana, but total eradication required ongoing hand weeding for a number of years to remove surviving or re-colonising plants.

Removal of egeria from bottom lined areas would be achieved within a year. Synthetic geotextile fabric panels were successful in removing invasive milfoil after 8 weeks placement in a US lake (Laitala et al. 2012). Jute hessian was successful in controlling lagarosiphon within as little as 4 months at lake sites (Caffrey et al. 2010). NIWA trials showed a denser hessian material and coconut fibre mat could successful remove egeria, lagarosiphon and hornwort within 5 months (Hofstra et al. 2010).

5.4.3 Practical considerations

Woven polypropylene weed matting is durable, but may be less acceptable in natural systems and eventual removal may be required. A restriction to the long-term effectiveness of this material for weed control is the rate of sedimentation at the site, which builds up a new rooting media over the mat enabling weeds to re-colonise if their propagules are available.

Submerged use of biodegradable materials suggests jute hessian lasts c. 7-10 months before disintegration (Caffrey et al. 2010). An additional advantage is the weave of these materials allows native plants to grow through from vegetative or seed sources, but larger submerged weeds like egeria or lagarosphon cannot (Caffrey et al. 2010, Hofstra et al. 2010). Benthic barriers may also provide some benefits analogous to geotextiles for bank and sediment stability, as well as encouraging native plant colonisation (Caffrey et al. 2010).

Bottom lining is difficult where there are emergent plant beds or obstacles (e.g., fallen trees). The transportation of the liners and other materials to the Gollans Wetland site is likely to require a helicopter. Additionally the temporary deployment of a watercraft on the open water area would be required if a large area of bottom lining is planned.

Installation within the pond depth (c. 1.2 m deep) would require snorkel or scuba divers to ensure liners are laid as overlapping strips. It will be important to ensure linings will not shift, especially in flood flows, so sufficient means of securement (e.g., sand bags, rocks, pins) would be needed to hold them in place. If gas production from sediments is substantial, the liners may need to be slit to vent gas build-up, which would reduce effectiveness as a barrier and increase the need for follow-up checks and hand weeding.

Estimates of costs for bottom lining are approximately \$3 m^2, excluding costs for checks and follow-up hand weeding, but may be higher for inaccessible sites (e.g., helicopter usage).

Bottom lining has little environmental risk. Effects of benthic lining on sediment-water nutrient dynamics are related to the permeability of the material used and sediment type, but might include increased or decreased release of reduced elements from beneath the barriers (Eakin and Barko 1995). Any nutrient release from the open water area would be spatially restricted and unlikely to have a major impact on the wider Lake Kohangatera/Gollans Wetland system given the level of dilution. Decreased dissolved oxygen and increased NH_4 beneath the lining may reduce macroinvertebrate densities (Ussery et al. 1997), however, macroinvertebrates may be able to migrate through permeable materials (Caffrey et al. 2010).

5.4.4 Possible implementation

- Installation of benthic barriers would be best timed for late winter to early spring when egeria has lower stature. Alternately, the removal of egeria biomass by diquat might be required prior to laying benthic barriers.
- In a flow through system such as the open water area of Gollans Wetland, orientation of liner strips should be parallel to flows to reduce the potential for dislodging.
- At least annual checks will ensure the lining has not shifted or identify if any repairs are required.

6 Recommended course of action

- An immediate application of diquat would reduce egeria biomass and height and would ensure fewer fragments are produced during winter when flood flows events are more likely to transfer the plant into Lake Kohangatera (seasonally higher lake levels and rainfall; GWRC data). Efficacy of this treatment should be confirmed by a post-spray visit after approximately 6 to 8 weeks, with potential for a follow-up spray at this time.
- Consideration should be given to obtaining a consent to treat the open water area within Gollans Wetland to 2 ppm (i.e., 57L of diquat). This is more likely to provide an effective herbicide concentration for egeria, but still with minimal impact for other aquatic life.
- Confirmation that egeria remains restricted to the upper Gollans Wetland open water area is recommended before any eradication attempt proceeds. (e.g., checks immediately upstream and downstream).
- Subsequently, assessment of an eradication method needs to be explored for feasibility and acceptability. Our assessment of the options suggests grass carp are the most feasible eradication option.
- If the grass carp option is pursued, the priority is an inspection of the inflow and outflow areas of the open water area for the most efficient means of fish containment. This will require a lead time, so should be initiated as soon as possible.
- Should grass carp be identified as an unacceptable option, we recommend that an integrated combination of herbicide application, artificial shading and/or bottom lining and hand weeding be developed with a view to containing egeria at the site and minimising the risk of downstream transport of fragments.
- If decision making requires more information on the potential future impacts of egeria on Lake Kohangatera, we would recommend an experimental assessment of egeria growth performance (c.f. elodea) under the salinity and sediment range typical of the lake (e.g., Wells et al. 2011).
- Access by the general public (e.g., duck shooters) to the upper Gollans Wetland open water area should be prohibited and reviewed annually.
- Access of watercraft to Lake Kohangatera should be discretionary, considering the risk of further introductions of water weeds (e.g., hornwort), or spread of egeria within the lake if it does occur there. However, the update to the status of elodea within the lake suggests lake-based boating is unlikely to be a factor in its distribution and spread around this lake.
- The movement of boats from Lake Kohangatera to Lake Kohangapiripiri should be prohibited to prevent accidental transfer of elodea to Lake Kohangapiripiri. If compliance with this restriction is difficult to enforce then a total ban on boating in Lake Kohangatera may need to be considered.
- Every effort should be made to educate lake users (e.g., duck shooters) or those carrying out activities in the catchment (e.g., eel fishermen, farmers, and agricultural contractors) of the risks of water weed introduction.

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Appendix A Upper catchment delimitation by GWRC

Summarised from an account provided by (Wayne Cowan (Senior Biosecurity Officer, GWRC, e-mail May 2012).

To delineate elodea and egeria in the upper catchment, GWRC, assisted by the land owner, inspected most of the Gollans Stream located on private property (Figure 5). The surveillance was concluded on the 3 May 2012, following two earlier investigations where observations had been limited by stream flows and clarity. The distribution of elodea was documented from the open section of stream beginning just south of the land owners dwelling, and extended downstream to the extent of the search area at the upper part of the Gollans Wetland (Figure 5). Elodea was observed to have invaded all open areas of the stream, typically forming high covers (Figure 6), with the exception of areas where fast flows and fine gravel did not provide a suitable anchorage for plants. Where the stream flow slowed and entered the wetland, elodea was apparently absent from the small accessible ponds that were checked by GWRC and the landowner.

No egeria was detected in the upper catchment.

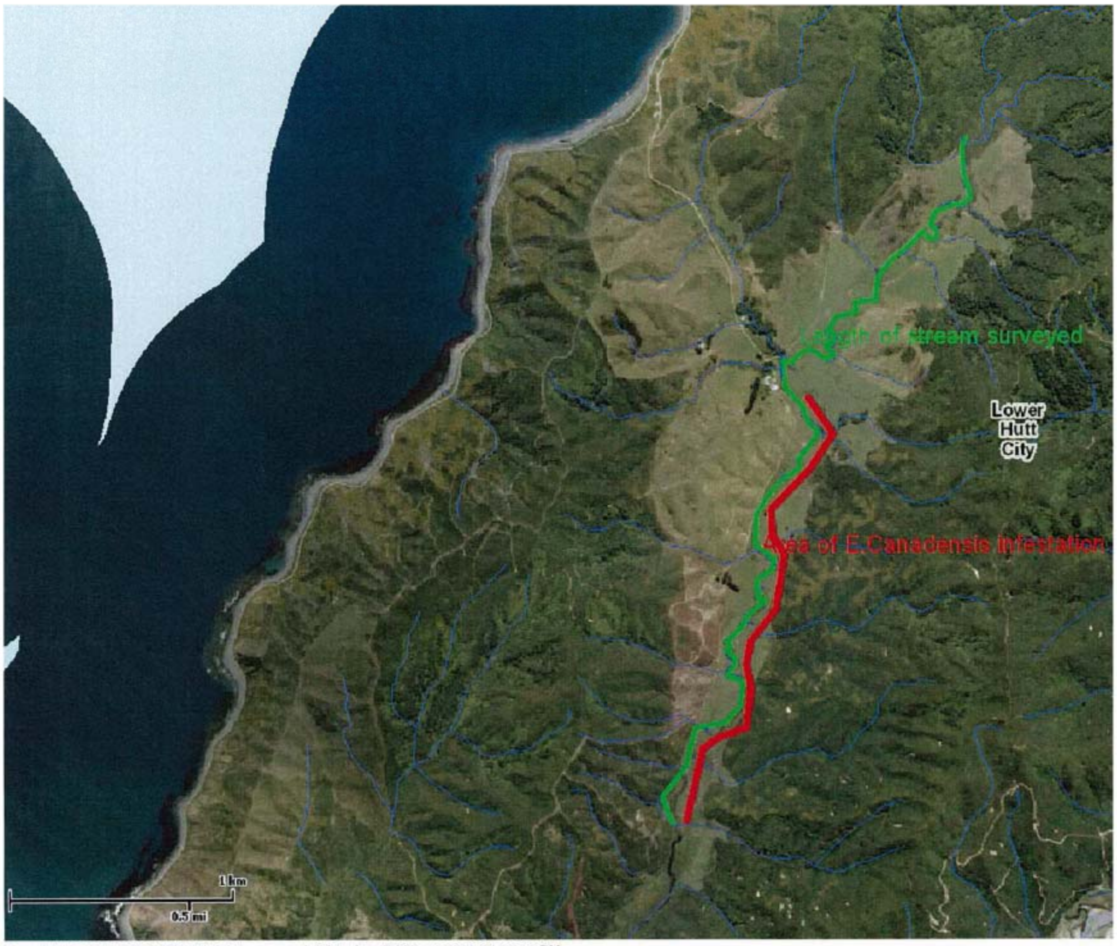

Figure 5: Section of the Gollans Stream checked by GWRC staff over three visits shown in green, with the extent of elodea distribution in red.

Figure 6: Typical growths of elodea in open areas of Gollans Stream in the upper catchment of Lake Kohangatera. (Photo: Wayne Cowan, Senior Biosecurity Officer, GWRC).