Lagarosiphon major IN LOUGH CORRIB – MANAGEMENT OPTIONS

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ABSTRACT

The highly aggressive submerged aquatic plant species *Lagarosiphon major* (Curly leaved waterweed) was recorded from nine sites in Lough Corrib, the second largest lake in Ireland, in 2005. One year later the plant had spread to 24 separate locations throughout the upper and middle lake and posed problems for amenity exploitation, principally wild brown trout fishing. Following a major survey in 2007, the plant had been positively identified from 64 locations. The largest plant stand occupies *circa* 19 hectares in Rinerroon Bay, north of Oughterard. It is noteworthy that no *Lagarosiphon* has yet been recorded from the lower lake.

Where *Lagarosiphon* has established large plant stands, no indigenous plants survive beneath the dense canopy cover. Thus, the lush Charophyte meadows for which many of the sheltered bays in Lough Corrib are famous are at risk of being eliminated.

In order to explore a range of weed control methods that might prove useful in limiting the spread of *Lagarosiphon* in the lake, and possibly eradicating it altogether, a number of pilot trials were undertaken in Rinerroon Bay in December 2006 and January 2007. Methods trialled included the use of the granular herbicide dichlobenil, mechanical cutting using V-blades, hand removal by scuba divers and light occlusion using submerged geotextile. Because of the success achieved using mechanical cutting, this trial was extended in September 2007. On this occasion, a section of bay measuring *circa* 4 hectares was treated.

Based on ongoing research on *Lagarosiphon* in Lough Corrib and following extensive consultations with international experts, a management programme for the lake is being formulated. If adequate funding is provided to the project, there is reason to be hopeful that *Lagarosiphon* can be brought under control and eradicated from large sectors of the lake.

INTRODUCTION

The protection of conservation and natural heritage values in Lough Corrib, a lake of national significance in Ireland, is incompatible with the presence and expansion of the aggressive invasive aquatic plant, *Lagarosiphon major,* that is currently being witnessed on the lake. In order to restore Lough Corrib to its acknowledged status as a fishery of international standing and a nationally important Special Area of Conservation, it is imperative that whatever action is necessary to effectively manage this invasive species is immediately taken.

Lagarosiphon major is an invasive, non-native, aquatic plant species that was first recorded in a natural aquatic habitat in Ireland in 2005. At that time, the plant was present in Rinerroon Bay on upper Lough Corrib and had established a surface canopy covering 12 ha of water. This dense, surface growth precluded recreational boating or angling in the bay and impacted indigenous floral and faunal communities that were resident in the area.

Preliminary research on Lough Corrib in 2005 revealed that *Lagarosiphon* had already invaded a number of other bays along the western shore of the upper lake. Knowledge of the invasive capacity and potential of this plant, and the environmental and economic damage that it has caused over a period of 40 years in New Zealand, gave rise to serious concerns for the conservation status and overall functioning of Lough Corrib.

In order to provide quantitative information on the status of *Lagarosiphon* in Lough Corrib, to determine the impact that this invasive species was having on indigenous biota, and to explore a range of options for managing the weed in the lake, the present study was undertaken.

INVASIVE SPECIES IN IRELAND

The number of non-native freshwater species recorded in Irish watercourses has increased significantly in the late1900s (Caffrey, 1994; Caffrey, 2001; Stokes *et al*., 2004). However, not all non-native species are invasive and current problems with invasive species are caused by only a small percentage of those that have been introduced to this country (Reynolds, 2002). The presence of a truly invasive species is evidenced by a demonstrable adverse impact on native communities or habitats.

Most of the problematic aquatic invasive species present in Ireland today were introduced in the last 20 years and some have been recorded here as recently as 2005 (e.g. *Eriocheir sinensis* (Chinese mitten crab) and *Leuciscus cephalus* (Chub)). The rate of species introductions to this country is accelerating, primarily because of increased international travel and trade.

The protection of Natura 2000 sites and features, as provided for in the Habitats Directive, is among the principal drivers for addressing the issue of invasive species and conservation of biodiversity. Aquatic invasive species clearly pose a major threat to the 'maintenance and restoration at favourable conservation status' of protected species and habitats and, as such, their establishment and spread must be controlled. According to the Directive (Article 6 – 1 and 2), Member States are obliged to address the issue of invasive species in their management plans and to take appropriate steps to avoid deterioration of habitats in Special Areas of Conservation (SAC).

Lagarosiphon major (Ridley) Moss

Lagarosiphon major (Curly leaved waterweed) is native to southern Africa, where its biomass can interfere with commercial navigation and water-based recreation (CEH, 2004). This species is acknowledged to be an aggressive invasive species in freshwaters. In Ireland *Lagarosiphon* is legally sold as an oxygenating plant for use in artificial watercourses. As a consequence, the plant is present in garden ponds, aquatic features on golf courses and in enclosed, artificial lakes at numerous locations throughout the country.

Lagarosiphon major is a perennial, submerged aquatic plant distinguished from closely related *Elodea* species because the leaves alternate spirally along the stems. The leaves have tapered tips, are strongly recurved downwards towards the stem and the leaf margins are minutely toothed. They typically cluster towards the apex of the stem. The stems are sparsely branched until they near the water surface. There they branch repeatedly to produce extremely dense mats on and below the surface. Outside its native range, only female plants are known (Cook, 1982) and all reproduction is by fragmentation or vegetative reproduction.

MATERIALS AND METHODS

Data on the distribution of *Lagarosiphon* in Lough Corrib (area 178 km^2) was collected using a range of methods included grapnel sampling along predetermined transects, viewing the lake bed using a glass-bottomed viewing tube, and scuba diving. All the littoral areas along the lake margins were surveyed. At sites where *Lagarosiphon* was recorded, the GPS coordinates were logged, associated aquatic plant species were identified and the depth range of the *Lagarosiphon* stand was measured. Where time and weather conditions permitted, the area of the lake occupied by *Lagarosiphon* was calculated.

In order to determine the impact that *Lagarosiphon* has on the indigenous flora present in Lough Corrib, aquatic plant samples were collected along defined transects in bays dominated by this invasive species. Similar data was collected in adjacent bays of similar aspect, chemistry and geology that had not yet been, or were only recently, colonised by *Lagarosiphon*. Species inventories and relative abundance values, as percentage bottom cover, were recorded along transects within these bays.

Pilot trials to determine the most effective methods to control *Lagarosiphon* were conducted in Rinerroon Bay (densely infested) and in Correrevagh Bay (an adjacent, recently infested bay) in December 2006 and January 2007. The trials were conducted in designated 50 x 50m plots. Control plots were established adjacent to the treatment plots. *Lagarosiphon* abundance, as percentage bottom cover within each plot, was estimated pre-treatment. Four weed control methods were trialled. These were: manual removal using scuba divers (in Correrevagh Bay), approved herbicide (dichlobenil), light occlusion using black geotextile and mechanical cutting. The results from the pilot trial were quantitatively evaluated in September 2007. Based on the results recorded from these treatments, an extended mechanical cutting trial in Rinerroon Bay was conducted in mid-September 2007.

RESULTS

A total of 2,058 sites in Lough Corrib were surveyed in 2007. The results demonstrated that *Lagarosiphon* has dramatically expanded its range in Lough Corrib since it was first reported in 2005. The number of sites known to be infested increased from 9 in 2005 to 24 in 2006, and to a high of 64 by September 2007 (Figure 1). No specimens of *Lagarosiphon* were recorded from the lower lake.

The two most densely infested sites on Lough Corrib are Rinerroon Bay on the west shore and Lazy Bay off the east shore (Figure 1). By far the largest *Lagarosiphon* population in the lake was present in Rinerroon Bay, where the plant was first reported. In 2005 the plant occupied an area of 12 ha. By the summer of 2007 the plant had extended its range within the bay to 19.45 ha. Based on the fresh weight biomass for *Lagarosiphon* recorded in 2005 (Caffrey, 2006; 2007), this represents an increased biomass over the two year period of 1,028 tonnes.

While only two bays in the lake had a *Lagarosiphon* coverage of greater that 10,000 m^2, a further eight sites contained populations that occupied between 1,000 and 10,000 m^2 (Figure 1). At a further eight sites, stands occupying between 100 and 1,000 m^2, were recorded. At the remaining sites examined in 2007 only scattered, low-growing populations of *Lagarosiphon* were recorded. Many of the stands occupied less that 1 m^2 and had probably only recently been colonised.

In most of the bays examined, notably where *Lagarosiphon* was absent, an abundant and diverse indigenous macrophyte flora was recorded. Charophytes were the dominant submerged plant group present and commonly occupied extensive, low-growing meadows, providing up to 100% bottom cover. Other macrophyte species that produced locally dominant stands were *Myriophyllum spicatum, Potamogeton lucens, P. perfoliatus* and *Elodea canadensis*. In Rinerroon Bay, few indigenous macrophyte species were recorded. Those that were present were depauperate or confined to localised areas where *Lagarosiphon* had not yet colonised. Beneath the dense canopy vegetation, a deep, unstable and anaerobic mud created an inhospitable environment for native aquatic plant species.

The progress of pilot control trials conducted on *Lagarosiphon* in Rinerroon and Correrevagh Bays in December 2006 and January 2007 was quantitatively assessed in September 2007. Neither manual removal by scuba divers nor the use of the approved aquatic herbicide, dichlobenil, proved effective in reducing the percentage cover of *Lagarosiphon* in the treatment plots (Table 1). In respect of the manual control, the lake substrate in which the *Lagarosiphon* was rooted was extremely fine and was brought into suspension with the slightest disturbance. Visibility was, therefore, reduced to zero once the plant removal operation commenced. In respect of the herbicide treatment, *Lagarosiphon* occupied *circa* 60% cover in the treatment plot at the time of spraying and a dense surface canopy was present. It is probable that a significant proportion of the herbicide granules applied became trapped within the vegetation and failed to reach the lake bed, which is the site of activity for dichlobenil (Caffrey, 1993a and 1993b). The net result would have been a non-toxic dose of dichlobenil in the mud within the trial plot.

Table 1. Results from weed control treatments on the percentage bottom cover of *Lagarosiphon major* in 50 x 50 m plants in Rinerroon and Correrevagh Bays in 2007.

	Treatment Plants		Control Plants	
	Pre-treatment	**September 2007**	**Pre-treatment**	**September 2007**
Hand Removal	<5%	10%	0%	0%
Herbicide	60%	75%	50%	65%
Uncut & Geotextile	90%	50%	100%	100%
Cut & Geotextile	70%	0%	100%	100%
Mechanical Cut	100%	8%	100%	100%

Black geotextile was used to block incident light from *Lagarosiphon* plants in two trial plots. In one plot the weed was cut prior to fixing the geotextile to the lake bed while, in the second, no weed cut was applied. Considerable difficulty was experienced sinking and securing the geotextile to the lake bed over this large area. In the cut plot the task proved less onerous and effective coverage of at least 80% of the plot was achieved. In the uncut section, less than 30% of the plot was effectively covered so that total light exclusion was achieved. The results obtained in September 2007 revealed that, where the cut had been applied, no vegetation was present in the area of the plot that was effectively covered. By contrast, at least 50% of the plot that did not receive a cut prior to geotextile placement supported healthy *Lagarosiphon* (Table 1).

A weed cutting boat equipped with a deep-cutting V-blade trailed on an 8 m-length of chain was used to apply the mechanical cut. The cut weed was immediately harvested and removed from the lake. In September, percentage bottom cover in this plot was *circa* 8% (Table 1). At least some of this new growth resulted because fragments from adjacent uncut areas had settled and rooted in the area of lake bed that was exposed by the cutting.

Because of the success achieved using mechanical cutting, an extended trial aimed at treating a significantly larger area of *Lagarosiphon* in Rinerroon Bay was conducted in September 2007. The V-blade was again used to cut vegetation. The cut weed was transported away from the lake to an isolated quarry, distant from any natural watercourses. During this five day trial, *Lagarosiphon* was removed from an area measuring *circa* 4.7 ha. *Circa* 300 tonnes of *Lagarosiphon* was removed from the bay during this operation.

DISCUSSION

While it is unknown when *Lagarosiphon* first entered Lough Corrib, or what the primary vector was, it is clear that the plant is now well established and truly invasive. The exponential increase in the number of sites from which the plant was recorded over the past three years bears testimony to this (9 in 2005, 24 in 2006 and 64 in 2007). This capacity to spread rapidly within suitable watercourses has also been observed in New Zealand where, within 13 years of its first record, *Lagarosiphon* came to occupy almost the full 161 km of littoral zone in Lake Taupo (Howard-Williams and Davies, 1988). This signifies the significant risk that the plant represents for the functioning of Lough Corrib as a fishery, as a conservation area or as a multi-purpose recreational resource.

In Lough Corrib, *Lagarosiphon* has adapted well to a wide range of physical and physico-chemical conditions. This adaptability has enabled the plant to actively compete with, and indeed to outcompete, native indigenous species and communities. One of the greatest competitive advantages that *Lagarosiphon* has over tall non-canopy forming native or naturalised species is its ability to produce a dense surface canopy. The canopy formed by *Lagarosiphon*, where mature surface-reaching stands have become established, is able to shade out, and competitively exclude, even tall submerged species. It has been demonstrated that as little as 1% sunlight can penetrate a canopy of 0.5 m deep (Schwartz and Howard-Williams, 1993).

Research has also demonstrated the competitive ability of *Lagarosiphon* fragments over those produced by other aquatic plant species (Rattray *et al*., 1994). Shoot fragments possess the ability to absorb nutrients from the water, as well as using stored nutrients. Where nutrients are plentiful in the water, *Lagarosiphon* channels its growth resources into shoot extension rather than into root development. This is particularly advantageous in aquatic situations where light may be limiting. Other plant species appear to require the development of an extensive root system before manifesting shoot growth.

The negative impact that mature *Lagarosiphon* stands can have on indigenous biotic communities is best reflected in the results from the macrophyte surveys conducted in designated bays in 2007. The littoral areas of most of the *Lagarosiphon*-free bays along the western shore of the lake are characterised by dense meadows of charophyte vegetation, mixed with tall stands of *Myriophyllum spicatum, Elodea canadensis* and a range of *Potamogeton* species. These abundant vegetation meadows extend to a depth of *circa* 4.5 m. Where *Lagarosiphon* produces expansive surface canopy vegetation, indigenous plant species are unable to compete. No charophyte vegetation and only small, localised stands of indigenous tall plant species were present in the *circa* 19 ha area that was overgrown with the invasive weed in Rinerroon Bay. This reflected the low light climate and the deep, anoxic mud deposits present beneath the canopy. This represents a dramatic loss of macrophyte biodiversity in Rinerroon and in the other lake areas where *Lagarosiphon* has become well established. It further threatens the unique macrophyte assemblages for which Lough Corrib is renowned.

The pilot weed control trials undertaken in Lough Corrib have demonstrated that hand pulling *Lagarosiphon* stems, using divers, will only be effective when targeted against small outlier populations in areas that are geographically isolated from other

Lagarosiphon stands. The use of light occluding geotextiles has proved successful in controlling submerged invasive weed species in New Zealand (Clayton, 1996) and in southern California (Woodfield, 2006). A high level of control with *Lagarosiphon* was achieved in Rinerroon Bay when the tall vegetation was cut prior to the material being laid. However, the material was difficult to fix to the lake bed and, where not pinned securely, it buoyed towards the surface and created a hazard for motorised craft.

Mechanical cutting using the V-blade provided effective weed control. Cutting can have the effect of stimulating plant regrowth and generally only achieves short-term control (Caffrey, 2003). The V-blade, however, is designed to rip the vegetation at root level from the lake bed, inflicting the maximum trauma to the plant. Clayton and Franklyn (2005) have shown that *Lagarosiphon* cannot regrow from root material left in the lake bed. This was supported by the finding from the present study where very little regrowth (8%) among the cut plants was recorded.

The extended trial conducted in September 2007 removed *circa* 300 tonnes of *Lagarosiphon* from an area of Rinerroon Bay measuring 4.7 ha. This operation served to demonstrate that large areas of lake containing a high standing crop of vegetation can be cleared, with obvious advantages for the lake and its overall management (e.g. reduced risk of detachment and spread of fragments, removal of a physical barrier to boat movements and angling, and the opportunity for recolonisation by native biotic communities).

In order to achieve control of *Lagarosiphon* in Lough Corrib, an informed and determined effort over a number of years will be required. Invasion ecology theory recommends that control efforts should focus on populations on the margins of range expansion as the most effective method of slowing or preventing further invasion (Moody and Mack, 1988). This approach alone will not work in Lough Corrib as the mature *Lagarosiphon* stands will continue to provide an inoculum of viable fragments to colonise new lake areas and to reinfest those areas where effective control has been achieved. It will, therefore, be necessary to target the new, low density and localised populations, while simultaneously addressing lake areas where mature, monodominant and high biomass stands are present. In the latter areas, if the funding or infrastructure is not available to implement plant control or removal, focus must be directed towards containing the plant (e.g. through the use of containment nets or floating barriers) and restricting movement by boaters into or out of these areas (e.g. by providing buoyed access lanes) while awaiting control.

While it will be important to explore new and innovative methods to control *Lagarosiphon* in Lough Corrib, particularly in respect of the opportunities afforded by biological control, there are sufficient tried-and-tested methods currently available to enable effective weed control to commence. With proper funding and a coordinated effort from relevant organisations, great strides towards significantly reducing the level of *Lagarosiphon* infestation in the lake can be made. It may not be possible to totally eradicate *Lagarosiphon* from this large expanse of water but it should be possible to achieve the following:
limit the spread of the plant within the lake;
eradicate new and low-density infestations;

significantly reduce the large biomass of vegetation at densely infested sites using mechanical control;
ensure that no *Lagarosiphon* becomes established in the lower lake; and
provide conditions for the natural recolonisation of previously infested areas by native species.

If the problem with *Lagarosiphon* in Lough Corrib, and the potential threat of it impacting other lakes in the country, is to be seriously addressed, long-term funding will be required. This commitment will provide the expertise and infrastructure to enable the project to be conducted in a professional manner and it will provide the continuity that contract staff require to fully engage in a worthwhile project of this nature.

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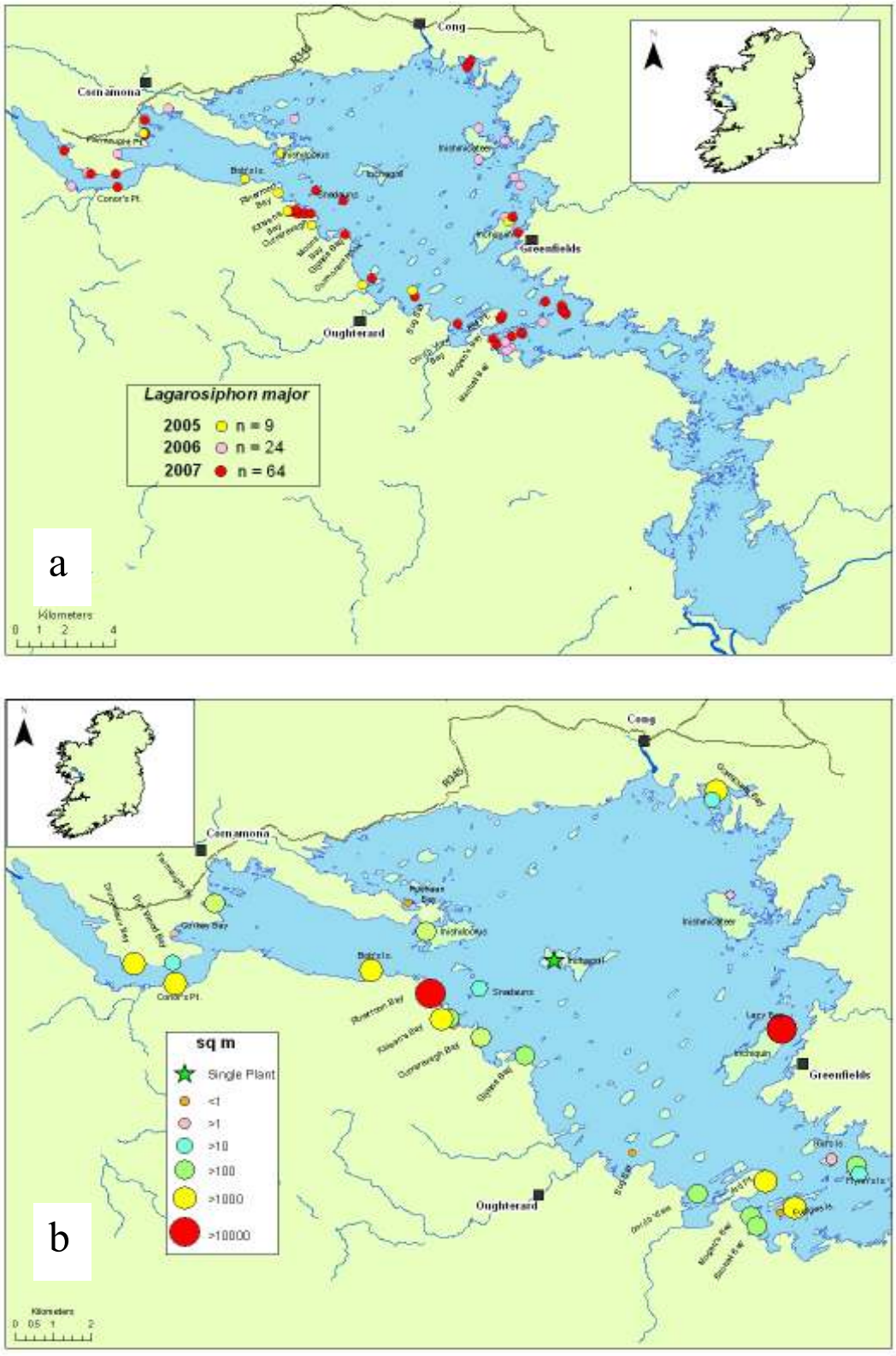

Figure 1. Map showing a) distribution of *Lagarosiphon major* populations in Lough Corrib in 2005, 2006 and 2007 and b) the relative abundance, as percentage bottom cover (m^2), of *L. major* populations in upper and middle Lough Corrib.