Caffrey, J, Millane, M, Evers, SL, Moran, H and Butler, M

A novel approach to aquatic weed control and habitat restoration using biodegradable jute matting

Aquatic Invasions (2010) Volume 5, Issue 2: 123-129
This is an Open Access article; doi: 10.3391/ai.2010.5.2.01

Research article

A novel approach to aquatic weed control and habitat restoration using biodegradable jute matting

Joseph M. Caffrey[1*], Michael Millane[1], Stephanie Evers[1], Helen Moran[1] and Martin Butler[2]

[1]*Central Fisheries Board, Swords Business Campus, Swords, Co. Dublin, Ireland*
[2]*Western Regional Fisheries Board, Teach Breac, Earl's Island, Galway, Ireland*
E-mail: joe.caffrey@cfb.ie (JMC), michael.millane@cfb.ie (MM), stephanie.evers@cfb.ie (SE), helen.moran@cfb.ie (HM), mbutler11@eircom.net (MB)
* *Corresponding author*

Received: 16 April 2010 / Accepted: 10 May 2010 / Published online: 15 May 2010

Abstract

This technical paper presents results from pilot field trials conducted on the novel use of a biodegradable jute material to eradicate the highly invasive aquatic macrophyte *Lagarosiphon major* Ridley from Lough Corrib, Ireland. The results demonstrate the ability of the jute material to comprehensively kill *L. major* and to restore native macrophyte communities to areas of the lake that were previously overgrown with this priority invasive species. To date, eight indigenous plant species (four charophytes and four angiosperms) have been recorded growing through the loose-weave jute fabric. However, no *Lagarosiphon* has been recorded as doing so. This material has the potential for broader application in the management of nuisance aquatic weeds and in the restoration of native flora extirpated by these alien species.

Key words: invasive species, *Lagarosiphon major*, macrophyte, management, benthic barrier

Introduction

Invasive non-native species pose a growing threat to Ireland's unique biodiversity and to economic interests in the country such as agriculture, forestry, fisheries and tourism. The impact of invasive aquatic species on biodiversity can be mediated by competitively excluding or out-competing the less robust native species, by preying on native species or by altering the natural aquatic or riparian habitat in which they reside. They can also adversely impact the recreational and amenity use of infested watercourses by restricting angling, boating, swimming and other water-based leisure pursuits (Caffrey 1993a, b; Stokes et al. 2004; Minchin 2007). Effective weed control in aquatic habitats can be difficult and the effects are commonly short-term. The methods most commonly applied under Irish conditions include mechanical control (cutting and harvesting, dredging) and the use of approved herbicides (Caffrey 1993b; Caffrey and Monahan 2006). These methods, however, can be highly disruptive, costly and relatively inefficient (Caffrey 1993b; Madsen 2000; Caffrey and Monahan 2006).

Another aquatic weed control method that is available but that has not received widespread management or scientific attention is light exclusion through the use of benthic barriers, often in the form of non-biodegradable plastic sheeting (Mayer 1978; Murphy 1988; Eichler et al. 1995; Cooke et al. 2005). The use of this material has considerable disadvantages as it is very difficult to sink and secure to a lake bed (Caffrey and Acevedo 2007). In addition, the gas evolution that results from decaying plant matter beneath the sheeting may affect the long-term functioning and stability of the method (Gunnison and Barko 1992) and may restrict the exchange of nutrients between the water column and the benthos (Mayer 1978). Furthermore, the method is often non-specific and may directly impact non-target biota, such as native macrophytes and macroinvertebrates (Eakin and Barko 1995; Ussery et al. 1997). As the plastic material commonly requires seasonal maintenance and ultimate removal from the habitat, the whole operation can incur significant costs.

The first confirmed sighting of invasive aquatic macrophyte *Lagarosiphon major* Ridley in Lough Corrib was at Rinnerroon Bay in the north-west of the lake in April 2005. It is believed, however, that the weed had been present in this area for a number of years prior to this (Caffrey and Acevedo 2007, 2008). *L. major* is a tall, canopy-forming and submerged macrophyte that is native to southern Africa. It is an aggressive and invasive species in lentic freshwater habitats. Since 2005 *L. major* has increasingly expanded its range throughout the northern and middle sections of the lake, typically colonising shallow sheltered bays (<6m water depth) and littoral areas. By 2008, the invasive weed had established viable populations at 113 sites. Where the plant successfully colonises, it is capable of rapidly producing a large biomass. In Rinnerroon Bay, for instance, a wet weight biomass of 1,650 tonnes (13.8 kgm^{-2}) was recorded in 2005. This had increased to 2,670 tonnes by 2007 (Caffrey and Acevedo 2007).

Lough Corrib is Ireland's second largest lake, with a surface area of c. 17,800 ha. The lake can be divided into three main parts; an upper basin, a relatively narrow middle section and a shallow lower basin. It is underlain primarily by carboniferous limestone to the east and south, and siliceous rocks to the north. The lake is of considerable ecological and conservation importance. It is designated as a Special Area of Conservation and includes 14 habitats and six species listed in the EC Habitats Directive (European Community 1992). It is an internationally renowned salmonid fishery notable for its wild brown trout and Atlantic salmon, and it attracts thousands of domestic and tourist anglers each year (Solon and Brunt 2006). Prior to the discovery of the invasive *Lagarosiphon major* in 2005, the native macrophyte community was dominated by a variety of charophyte, *Myriophyllum* and *Potamogeton* taxa. The charophyte communities commonly predominated, forming extensive beds or meadows in shallow areas throughout the lake (Krause and King 1994).

Key invasive attributes of *L. major* include its ability to quickly colonise suitable habitats, its very rapid growth rate, its capacity to create a dense, light-excluding canopy layer on the water surface and its ability to disperse widely via plant fragments. A unique trait of this plant in Ireland is its ability to actively grow during the winter months when most indigenous species have died back (Caffrey and Acevedo 2007; Caffrey et al. 2009). It is noteworthy that the plant is sterile and that only female plants are present in Ireland. Research conducted on *L. major* in Lough Corrib has revealed the plant's capacity to totally displace native charophyte-dominated macrophyte communities at infested sites. This is an important keystone habitat in the lake (Caffrey and Acevedo 2007; Caffrey et al. 2009). In addition, the extensive canopy produced by the invasive plant can carpet the water surface of entire bays thus restricting their exploitation for angling and boating (Caffrey and Acevedo 2007). Furthermore, the density and growth form of the plant substantially alters the habitat features of infested areas, affecting the resident macroinvertebrate fauna by significantly altering their community structure. In turn, this has the potential to negatively influence fish community composition, rendering the habitat more suitable to cyprinid fishes, pike and perch than to salmonids, for which this lake is renowned both nationally and internationally (Champ 1993; Krause and King 1994; Caffrey et al. 2009; O'Grady et al. 2009).

The primary objective of the present study was to investigate the efficacy of a natural light excluding material, namely jute, to control *L. major* in targeted areas of Lough Corrib. It was further proposed to examine the nature and rate of natural recovery among native plant species at treated sites. This paper will present results from pilot field trials conducted in the lake between 2008 and 2010.

Materials and methods

Seven *L. major* dominated sites were treated with jute matting between August 2008 and October 2009 (Figures 1, 2 and Table 1). The areas of lake bed covered varied between 100 and 5000 m^2. The length of time the jute matting was in place ranged from 4 to 17 months. Before placing the jute matting the extent of the infestation with *L. major* at each sampling location was recorded as follows: total cover = 1 (where the plant occupied *circa* 100% and no other macrophyte species were present) and extensive dense patches = 2 (where *L. major* was the dominant plant but small stands of native species or areas of exposed lake bed were present). At the end of the trial period a series of measurements were recorded at each site. These included: a) status of *L. major* having been covered for a specific duration (live and intact = 1, decaying = 2, fully decomposed = 3); b) condition of jute matting (intact = 1, intact but easily torn = 2, intact but disintegrates on contact = 3); c) extent of sedimentation on jute matting (none = 1, partially covered = 2, jute not visible beneath sediment = 3); and d) speciation and percentage cover of native plants on the jute matting. These data were recorded by divers using five randomly placed 0.25 m^2 quadrats at each site. The status of *L. major* beneath the matting was assessed *in situ* by making a small incision in the material and inspecting the plant material, both visually and manually. The extent of sedimentation was assessed visually.

A natural and biodegradable material was sought to replace plastic or polyethylene sheeting commonly used for light exclusion in aquatic weed control programmes. Rolls of jute matting (5 m wide × 900 m long, *circa* 200 gm^{-2}) were sourced and trialled on *L. major* in Lough Corrib. Jute is a natural vegetable fibre and the matting used is loose-woven (Figure 3) and durable. Another beneficial characteristic of the product for application in large lake situations is the fact that it saturates on contact with water and rapidly sinks, thus limiting the impact that wind can have on its accurate placement.

Depending on the size of the area to be treated, two methods for applying the jute matting have been developed. Where *L. major* occupies an area in excess of 200 m^2, a purpose-modified boat is utilised. The matting is deployed from a boat-mounted dispenser directly onto the water surface (Figure 4). The site to be treated is demarcated by divers using buoys. An estimate of the area to be treated is made and sufficient material to complete the operation is

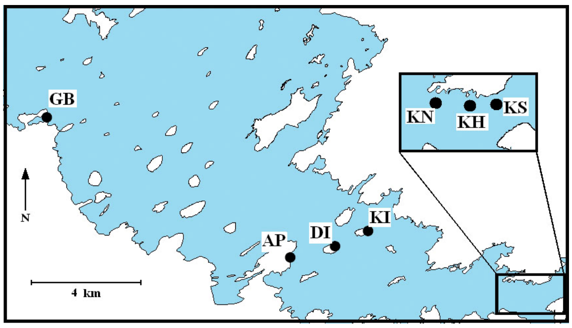

Figure 1. Sites in Lough Corrib where jute matting was deployed to control the invasive *Lagarosiphon major* (AP = Ard Point; DI = Devinish Island; GB = Gortdrishagh Bay; KI = Kid Island; KH = Kilbeg Harbour; KN = Kilbeg North; KS = Kilbeg South).

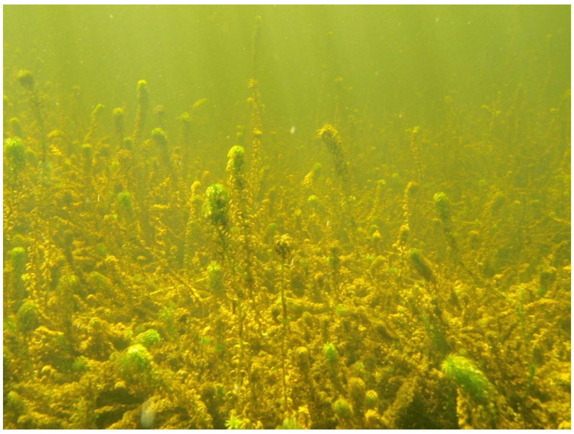

Figure 2. Typical *Lagarosiphon major*-dominated habitat prior to jute application (photograph by Joe Caffrey).

Figure 3. A view through the open-weave jute matting used to kill *Lagarosiphon major* in Lough Corrib (photograph by Joe Caffrey).

Figure 4. Jute matting application using a purpose modified boat (photograph by Joe Caffrey).

Figure 5. Jute matting secured *in situ* on the lake bed (photograph by Joe Caffrey).

Figure 6. *Nitella flexilis* growth on the jute matting 8 months after application at site Ard Point (photograph by Joe Caffrey).

prepared onshore. The jute is commonly laid in 100 m-long strips. Divers are present in the water to oversee the accurate placement of the material and to ensure that strips overlap properly, where this is required. Small weights are attached along each side of the matting, at roughly 5 m intervals, as the material is being laid on the water. This aids in its proper placement on the target weed bed. The matting is secured on the lake bed by the divers using additional weights or pins (Figure 5). Alternatively, where smaller beds of *L. major* (< 200 m^2) are the primary target, pre-cut sheets of the jute (each ≤ 5 m × 15 m) are manually laid over the target weed bed from a boat or are brought into position by divers from the shore. As before, the material is secured in place by divers.

Results

At all seven treated sites the growth of *Lagarosiphon major* was effectively controlled by the placement of the light excluding jute matting (Table 2). At all but one site (Kilbeg North) the invasive weed was completely decomposed beneath the matting, even where the matting was in place for only 4 months (Kid Island). At the Kilbeg North site, one small (< 1 m^2) intact *L. major* stand was present in a small fold at the edge of the mat.

Up to seven months after placement in the lake, the jute matting maintained its integrity and could not be easily torn. After 10 months, at Devinish Island, the matting appeared to be functionally intact but was relatively easily torn when gentle pressure was applied. At Ard Point, where the material had been *in situ* for 17 months, it again appeared to be intact (in that the weave was visible when the deposited sediment was removed) but it disintegrated on contact. The extent of sedimentation on the matting was variable from site to site, but tended to increase with increasing time from application (Table 2).

At all of the sites where seven or more months had elapsed since the jute matting was put in place, some level of growth among native macrophyte species was recorded on the material (Table 3). The charophyte *Nitella flexilis* agg. L. was present at each of these sites. It is noteworthy that this species was also observed, albeit as a few strands, growing through a small unsampled section of the matting at Kid Island, where the material had been in place for only four months. Three other charophyte species, namely *Chara globularis* Thuill., *Chara rudis* A. Braun Leonh and *Chara virgata* Kütz, were also recorded growing through the jute matting. *C. virgata* was present at Ard Point and Devinish Island and clearly dominated the vegetation at the former site. In addition, this species was found to be established in an unsampled area of the jute at Gortdrishagh Bay. The remaining species were each recorded at a single location (Table 3). At five of the sites an appreciable percentage cover among native charophyte species was recorded (Table 3).

A number of indigenous or naturalised angiosperm species were also recorded growing through the weave of the jute matting. These included *Myriophyllum alterniflorum* De Candolle, *M. spicatum* L. and *Elodea canadensis* Michaux. None were recorded growing with any significant abundance (Table 3). At sites not

Table 1. Sites in Lough Corrib where jute matting was deployed to control the invasive macrophyte *Lagarosiphon major* between 2008 and 2009.

Site	Site code	Coordinates		Approximate area of jute laid (m^2)	Months from laying to sampling
		Latitude (N)	Longitude (W)		
Ard Point	AP	53°25'53"	09°14'17"	1500	17
Devinish Island	DI	53°26'03"	09°13'15"	150	10
Kilbeg Harbour	KH	53°25'32"	09°08'45"	175	7
Kilbeg North	KN	53°25'36"	09°09'04"	100	7
Kilbeg South	KS	53°25'32"	09°08'30"	100	7
Gortdrishagh Bay	GB	53°27'45"	09°19'57"	5000	5
Kid Island	KI	53°26'16"	09°12'30"	1500	4

Table 2. Results from quadrat analyses conducted at the seven *Lagarosiphon major* dominated sites treated with jute matting between 2008 and 2009. Five randomly placed 0.25 m^2 quadrats were examined at each site.

	Mean (± SE)						
Site code	AP	DI	KH	KN	KS	GB	KI
Extent of *L. major* colonisation before treatment†	1	1	2	2	2	1	2
Time since application (months)	17	10	7	7	7	5	4
Status of *L. major**	3	3	3	2.6 (0.4)	3	3	3
Condition of jute**	3	2	1	1	1	1	1
Extent of sedimentation on jute***	2.8 (0.2)	2.4 (0.25)	1.2 (0.2)	1	1	2	1

Site code: AP = Ard Point; DI = Devinish Island; GB = Gortdrishagh Bay; KI = Kid Island; KH = Kilbeg Harbour; KN = Kilbeg North; KS = Kilbeg South).
†1 = total cover, 2 = extensive dense patches. * status of *L. major* (live and intact = 1, decaying = 2, fully decomposed = 3); ** condition of jute (intact = 1, intact but easily torn = 2, intact but disintegrates on contact = 3); *** extent of sedimentation on jute (none = 1, partially covered = 2, jute not visible = 3).

Table 3. Percentage vegetation cover at the seven *Lagarosiphon major* dominated sites treated with jute matting between 2008 and 2009. Five randomly placed 0.25 m^2 quadrats were examined at each site.

	Mean (± SE)						
Site code	AP	DI	KH	KN	KS	GB	KI
Chara virgata (Kütz)	71.6 (17)	16 (10.3)	-	-	-	-	-
Nitella flexilis agg. (L.)	4.4 (0.6)	34 (14.4)	66.8 (15.7)	42.4 (18.8)	27.2 (15)	-	-
Chara globularis (Thuill.)	-	-	18 (16.7)	-		-	-
Chara rudis ((A. Braun) Leonh.)	-	-	-	-	10 (7.6)	-	-
Elodea canadensis (Michaux)	0.4 (0.4)	7 (2)	-	0.2 (0.2)	0.2 (0.2)	-	-
Myriophyllum spicatum (L.)	-	2 (2)	0.4 (0.4)	0.2 (0.2)	-	-	-
Myriophyllum alterniflorum (De Candolle)	-	-	-	1.2 (1)	1 (1)	-	-
Lagarosiphon major† (Ridley)	2 (1.2)	-	-	-	0.2 (0.2)	-	-

† unrooted fragments; standard error in brackets

included in the current study, moderate stands of *Potamogeton pusillus* L., in addition to occasional *P. lucens* L. plants, were observed growing through the jute matting.

Discussion

The use of black plastic or black polyethylene sheeting for aquatic weed control has been described (Born et al. 1973; Nichols 1974; Cooke and Gorman 1980; Eakin and Barko 1995). Although successful for the short-term control of vegetation in treatment plots, this material has a number of disadvantages. It is difficult to work with because of its inherent buoyancy. As the material does not readily biodegrade in water, it cannot be deemed to represent an environmentally friendly weed control method. Furthermore, the limited permeability of this material has been shown to create anoxic conditions and increased ammonium concentrations beneath the sheeting. This can result in the elimination of native aquatic macroinvertebrate communities (Eakin and Barko 1995). Because no plants can grow through the material, there is little opportunity for recovery or restoration of native macrophyte communities.

The jute matting employed in the present trials has a number of advantages over plastic or polyethylene sheeting. The fact that it is made from a natural, biodegradable fibre means that it will not be necessary to incur costs associated with removing the material from the water once it has achieved its goal. The material is durable and, hence, easy to handle. The material saturates rapidly on contact with water and sinks within minutes of laying it on the lake surface; this makes it easy to place accurately, particularly in windy conditions. As the material is permeable it permits gases to escape and prevents the development beneath the matting of anoxic conditions. It also enables the free movement of water and some macroinvertebrate species.

Results from this pilot study have demonstrated the capacity of this jute matting to effectively control *L. major* at treated sites in Lough Corrib. It is noteworthy that this process can take less than four months.

One highly beneficial, although unexpected, consequence of the treatment was the relatively rapid recovery, through the weave in the jute matting, of indigenous plant species and communities. Within seven months of placing the matting over dense *L. major* beds, relatively dense beds of native macrophyte species were observed growing through the material (Figure 6). Moreover, the presence of *C. virgata* at Gortdrishagh Bay and *N. flexilis* at Kid Island suggests that this regeneration process can commence in as short a time period as four to five months after the matting is applied. The emergence of *C. rudis* through the matting, at Kilbeg South, was somewhat unexpected as this is one of the physically larger charophyte species present in the lake. It was thought that its large size might preclude it from growing through the weave in the matting.

It is apparent that the death of the *L. major* beneath the jute mat provided conditions that favoured the germination of dormant charophyte oospores and angiosperm seeds. It is also probable that the physical framework of the jute matting on the lake bed provided stability for the emerging plants. The material may help stabilise the bottom sediments, thus allowing native plants and, in particular, charophytes to establish. Alternative weed control methods can leave the lake bed relatively denuded of vegetation and the sediment unstable. By contrast, the jute matting appears to stabilise the sediment on the lake bed while also providing a stable platform on or through which native macrophytes can grow. Indeed, the jute may have a secondary application as an effective framework for sediment stabilisation in waterbodies where sediment disturbance, for whatever reason, is a feature.

Prior to the invasion with *L. major*, Lough Corrib was renowned for the extensive charophyte meadows that characterised large areas of the waterbody. Nine species of charophyte have been recorded here (Krause and King 1994). It is noteworthy that, of these, four species were recorded in the treated areas. It is also significant that these charophyte species are capable of establishing large vegetation meadows in areas where the invasive *L. major* has been covered. The re-establishment of small populations of a number of angiosperm species is also encouraging.

There have been relatively few advances in applied methods for weed control in recent years. The use of the biodegradable jute matting provides a novel and environmentally sensitive method of controlling the highly invasive *L. major*. A significant benefit allied with the method is the capacity to restore, without added intervention, natural habitat conditions following the removal of the intrusive invasive plant. The method has the potential for broader application in the management of aquatic invasive plant species and in the restoration of native flora extirpated by these weeds.

The information presented in this technical paper represents the results from a pilot field study. Research is currently in progress that will provide more quantitative detail regarding the effectiveness of this method in the long-term restoration of impacted native macrophyte and other biotic communities in Lough Corrib.

Acknowledgements

This CAISIE (Control of Aquatic Invasive Species and Restoration of Natural Communities in Ireland) project is funded with the contribution of the LIFE financial instrument of the European Community, with co-financing from the National Parks and Wildlife Service. Particular thanks to Greg Forde, Tommy Kelly and all of the Western Regional Fisheries Board staff that were associated with this project. Thanks to Nick Stewart for assisting with some of the charophyte identifications. The paper reviewers and the support of Shireen Sayed (Central Fisheries Board) are gratefully appreciated.

References

Born SM, Wirth TL, Brick EM, Peterson JP (1973) Restoring the recreational potential of small impoundments. The Marion Millpond experience. Department of Natural Resources, Madison, WI. Technical Bulletin No. 71

Caffrey JM (1993a) Aquatic plant management in relation to Irish recreational fisheries development. *Journal of Aquatic Plant Management* 31: 162-168, doi:10.1051/hydro:1993104

Caffrey JM (1993b) Plant management as an integrated part of Ireland's aquatic resource. *Hydroécologie Appliquée* 5: 77-96

Caffrey JM, Monahan C (2006) Control of *Myriophyllum verticillatum* L. in Irish canals by turion removal. *Hydrobiologia* 570: 211-215, doi:10.1007/s10750-006-0183-3

Caffrey JM, Acevedo S (2007) Status and management of *Lagarosiphon major* in Lough Corrib - 2007. Central Fisheries Board, Dublin, 119 pp

Caffrey JM, Acevedo S (2008) *Lagarosiphon major* in Lough Corrib – management options. In: Moriarty C, Rosell R, Gargan P (eds), Fish Stocks and their Environment. Institute of Fisheries Management, Westport, Co Mayo, pp 85-97

Caffrey JM, Evers S, Moran H (2009) Research and control programme for *Lagarosiphon major* in Lough Corrib 2008. Central Fisheries Board, Dublin, 159 pp

Champ WST (1993) Lough Sheelin - a 'success' story. In: Mollan C (ed), Water of Life. Royal Dublin Society, Dublin, pp 154-162

Cooke GD, Gorman ME (1980) Effectiveness of DuPont Typar Sheeting in controlling macrophyte regrowth after overwinter drawdown. *Water Resources Bulletin* 16: 353-355

Cooke GD, Welch EB, Peterson S, Nichols SA (2005) Restoration and Management of Lakes and Reservoirs. CRC Press CRC Press, Boca Raton, 591 pp, doi:10.1201/9781420032109

Eakin HL, Barko JW (1995) Evaluation of the effect of benthic barrier placement on sediment physical and chemical conditions. U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS, Technical report A-95-2

Eichler LW, Bombard RT, Sutherland JW, Boylen CW (1995) Recolonization of the littoral zone by macrophytes following the removal of benthic barrier material. *Journal of Aquatic Plant Management* 33: 51-54

European Community (1992) Directive 92/43/EC on the conservation of natural habitats of wild fauna and flora. *Official Journal of the European Union* L 206: 7-50

Gunnison D, Barko JW (1992) Factors influencing gas evolution beneath a benthic barrier. *Journal of Aquatic Plant Management* 30: 23-28

Krause W, King JJ (1994) The ecological status of Lough Corrib, Ireland as indicated by physiographic factors, water chemistry and macrophytic flora. *Vegetatio* 110: 149-161, doi:10.1007/BF00033395

Madsen JD (2000) Advantages and disadvantages of aquatic plant management techniques. U.S. Army Engineer Research and Development Center. Vicksburg, MS, Final report, ERDC/EL MP-00-1, 31 pp

Mayer JR (1978) Aquatic weed management by benthic semi-barriers. *Journal of Aquatic Plant Management* 16: 31-33

Minchin D (2007) A checklist of alien and cryptogenic aquatic species in Ireland. *Aquatic Invasions* 2: 341-366, doi:10.3391/ai.2007.2.4.4

Murphy KJ (1988) Aquatic weed problems and their management: a review. II. Physical control measures. *Crop Protection* 7: 283-302, doi:10.1016/0261-2194(88)90075-0

Nichols SA (1974) Mechanical and habitat manipulation for aquatic plant management. A review of techniques. Department of Natural Resources, Madison, WI, Technical bulletin No. 77, 34 pp

O'Grady MF, Kelly M, O'Reilly S (2009) Brown trout in Ireland. Irish Freshwater Fisheries Ecology and Management Series: Number 6. Central Fisheries Board, Dublin, Ireland, 122 pp

Solon E, Brunt B (2006) Angling resources in Lough Derg and Lough Corrib: perceptions of visiting anglers. *Irish Geography* 39: 34-51, doi:10.1080/00750770609555865

Stokes K, O'Neill KP, McDonald RA (2004) Invasive species in Ireland. Report to Environment and Heritage Service and National Parks and Wildlife Service. Quercus, Queen's University Belfast, Belfast, 151 pp

Ussery TA, Eakin HL, Payne BS, Miller AC, Barko JW (1997) Effects of benthic barriers on aquatic habitat conditions and macroinvertebrate communities. *Journal of Aquatic Plant Management* 39: 69-73