

Removal and monitoring of Himalayan Balsam *Impatiens glandulifera*

- Monitoring Report



Action C10

LIFE09 NAT/IE/000220 BLACKWATER SAMOK

June 2015

The IRD Duhallow LIFE Project is supported through the LIFE financial instrument of the European Community.



I.R.D. Duhallow Ltd.



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Executive Summary

Himalayan balsam *Impatiens glandulifera* is an invasive non-native annual plant introduced to Ireland in 1839 from its native range in the Himalayas. In Ireland it is most invasive in damp habitats particularly along river corridors, where it out-competes native vegetation in summer and dies back in winter, exposing river banks to erosion. It spreads rapidly downstream in river catchments due to its prolific seed production.

Himalayan Balsam was identified as an issue along the River Allow during preliminary survey work in 2009. The River Allow catchment (Rivers Allow, Dalua, Brogeen, Glenlara and Owenkeale) form part of the Blackwater River (Cork/Waterford) Special Area of Conservation (Natura 2000 site code: 002170).

On commencement of the LIFE project in 2011, detailed field survey found that 5km of river channel was infested with Himalayan Balsam. The source of the plant in the catchment was found to be an infestation at the James O’Keeffe Institute in Newmarket, apparently having been grown in Newmarket Demesne as an ornamental plant in the 1950s. Trial plots were established at this site to help characterise the growth rate, plant density and timing of flowering of the species in this part of Ireland. Prior to beginning the removal effort, a network of twenty-two permanent 1m² quadrats was set up between Kanturk and the Allow/Blackwater confluence, and the vegetation in the quadrats was assessed. This included the number of individual plants of Himalayan Balsam and the proportion of bare ground within each quadrat, and well as the proportion of cover of other plant species.

Removal of the plant was carried out by hand-pulling and placing the plant material into 50kg fertiliser bags. This material was then stored in a plastic-lined pit until it had rotted down and was no longer viable. Plants which had gone to seed were treated by enclosing the head of the plant in a plastic bag before cutting the stem below the bag.

Vegetation monitoring at the quadrat locations and walkover surveys were carried out annually from 2012 to 2015 inclusive. The most striking outcomes of the removal programme were the low regrowth of Himalayan Balsam, and the rapid recovery of native vegetation. Over the four years of monitoring only two plants of Himalayan Balsam were found in one quadrat in 2015. All quadrats showed significant vegetation recovery in the first year after removal, with those in high light conditions having complete cover of native grass and herb species. Shaded sites

were slower to recover. The average proportion over all quadrats of grasses to broadleaved herbaceous species was higher in the first year, levelling off to approximately equal proportions in subsequent years. Colonisation by another invasive species, Japanese Knotweed, was noted at one of the monitoring quadrats.

Results from the Newmarket trial site suggest that Himalayan Balsam in open ground conditions is more productive both in terms of the height of plants and the number of flower heads per plant, when compared with plants growing in shaded conditions; and that the species is more productive in shaded dry conditions than shaded damp sites.

The findings from the vegetation monitoring aspect of the project demonstrate clearly the effect that monospecific stands of Himalayan Balsam have on native riparian vegetation, and also the robustness of that vegetation in recovering once the invasive plant is removed.

Although an intensive removal effort over a full growing season is initially required to clear stands of the plant, the outcomes of this project show that this is a highly effective approach over the short to medium term (up to four years' post-removal) at a minimum. Factors to consider in targeting future control efforts in this and other similar catchments are the high productivity and earlier flowering of the invasive plant in open conditions, and the apparent slower recovery of shaded habitats. Identifying the seed source (i.e. furthest upstream colony) of the invasive plant is important for catchment-wide control over the longer term.

Background

Invasions by non-native species represent one of the greatest threats to natural biodiversity, second only to habitat destruction (Scalera & Zaghi, 2004). Biological invasions cause ecological and economic impacts across the globe (Vilà, et al., 2011). According to Invasive Species Ireland "Invasive non-native plant and animal species are the second greatest threat to biodiversity worldwide after habitat destruction. They can negatively impact on native species, transform habitats and threaten whole ecosystems causing serious problems to the environment and the economy". Non-native and invasive species can transform ecosystems, threatening both indigenous and high conservation status species with impacts including displacement through competition for space and food (Stokes, O'Neill, & McDonald, 2006).

Himalayan Balsam

Himalayan balsam, *Impatiens glandulifera* is an invasive non-native plant to Ireland. Introduced to Ireland in 1839 from its native range in the Himalayas (Invasive Species Ireland, 2015), *I. glandulifera* spread from ornamental gardens in which it was being cultivated (Prowse, 2001). Infestation along waterways is especially rapid as the seeds are waterborne and moving water is an ideal vector for the plant's transmission (Helmisaari, 2010; Kelly et al, 2008).

I. glandulifera grows up to 3 metres high with a hollow and bamboo-like, hexagonal stem, pink-red to green in colour with green vertical grooves. The plant produces purplish to pale pink flowers in mid-late summer (Helmisaari, 2010). On rare occasions flowers are white (Prowse, 2001). Seed pods are carried on long stalks between June and October and resemble an elongated pear. When disturbed or touched, they split, resulting in seeds literally exploding from the plant. Each plant can produce around 2,500 seeds that can be propelled up to 7 metres in distance (Inland Fisheries Ireland, 2015; Prowse, 2001, Anon., n.d). Seeds that enter watercourses can travel over 10 km before germinating in the spring. The plant is mainly found on riverbanks and damp ground. It spreads predominantly along watercourses but is also spread by human interaction. The spread of *I. glandulifera* is of major concern in the UK (Tanner, et al., 2013; Tanner, n.d).

Impacts of Himalayan balsam

I. glandulifera is fast growing and can out-compete native plants for light and space, overshadowing them and hampering their growth (Kelly *et al.*, 2008). It also successfully competes

with native plants for pollinators (Tanner, *et al.*, 2011). It forms dense stands which suppress the growth of native grasses and forbs leaving the banks bare of vegetation in autumn and winter and liable to erosion.

It is also likely that the invertebrate community composition normally associated with native riparian vegetation will be negatively affected, potentially impacting on predators (Tanner, *et al.*, 2013; Levine, *et al.*, 2003) associated with rivers such as fish and riparian birds (Tanner, *et al.*, 2013).

As an annual plant, *I. glandulifera* dies back in winter, often leaving bare soil which is easily eroded during wet periods (Inland Fisheries Ireland, 2015; Alberta Invasive Species Council, 2014). Infestations along rivers and streams are of particular concern as river banks infested by *I. glandulifera* may be very susceptible to erosion (Inland Fisheries Ireland, 2015; Hubble *et al.*, 2009) in Winter and early Spring. The resulting soil erosion causes sedimentation of the river bed which can cause problems for fish species and aquatic invertebrates (Hendry & Cragg-Hine, 2003; Thorne, 1990). *I. glandulifera* will take advantage of soil disturbance and flourishes in nutrient rich, alluvial soils found in riparian zones and wet woodlands (Alberta Invasive Species Council, 2014). Its seeds will even germinate under water (Wye Valley, 2009).

Additionally, work by Ruckli *et al.* (2014, and ongoing) demonstrates an inhibitory effect on native vegetation by *I. glandulifera* due to the release of naphthoquinones (allelochemicals) from the plant into the surrounding soil. These chemicals were found to affect the growth of woodland trees, herbs and associated mycorrhizal fungi, and can be caused both by the living plant and by decaying plant material.

Although native to the western Himalayas *I. glandulifera* is perfectly adapted to the climate of northern and central Europe, temperate North America and New Zealand (Weber, 2003). *I. glandulifera* is considered one of the highest risk non-native invasive species in Ireland (Invasive Species Ireland, 2015).

Himalayan balsam in the Blackwater River Catchment

The presence of *I. glandulifera* in the Blackwater Catchment is well documented (e.g. Kelly, *et al.*, 2009). Preliminary survey work carried out in June 2009 by Inland Fisheries Ireland staff and IRD Duhallow identified *I. glandulifera* in the upper reaches of the catchment. Large, well established dense stands were found along riparian areas along the lower reaches of the River

Allow. A questionnaire was also circulated amongst key stakeholders as part of this survey. Responses obtained from regular river users (including anglers) indicated that *I. glandulifera* was spreading rapidly throughout the catchment and established stands were becoming denser, making the angling experience less enjoyable.

Prior to the commencement of the DuhallowLIFE project in 2011 the distribution of *I. glandulifera* on the River Allow was estimated to occur from Kanturk Town to the confluence with the main River Blackwater channel, a distance approximating 5km.

Objective:

The River Allow catchment (Rivers Allow, Dalua, Brogeen, Glenlara and Owenkeale) form part of the Blackwater River (Cork/Waterford) Special Area of Conservation (Natura 2000 site code: 002170). *I. glandulifera* was recorded in large infestations along the River Allow and River Dalua (and subsequently the Brogeen River) during survey work in 2009.

Key objectives of this action were to

1. Remove/control *I. glandulifera* within the upper reaches of the Special Area of Conservation.
2. Develop an *I. glandulifera* management strategy transferable to other catchments.
3. Plan for an exit strategy to maintain the programme after the LIFE project has ceased (afterLIFE phase).

Site Description

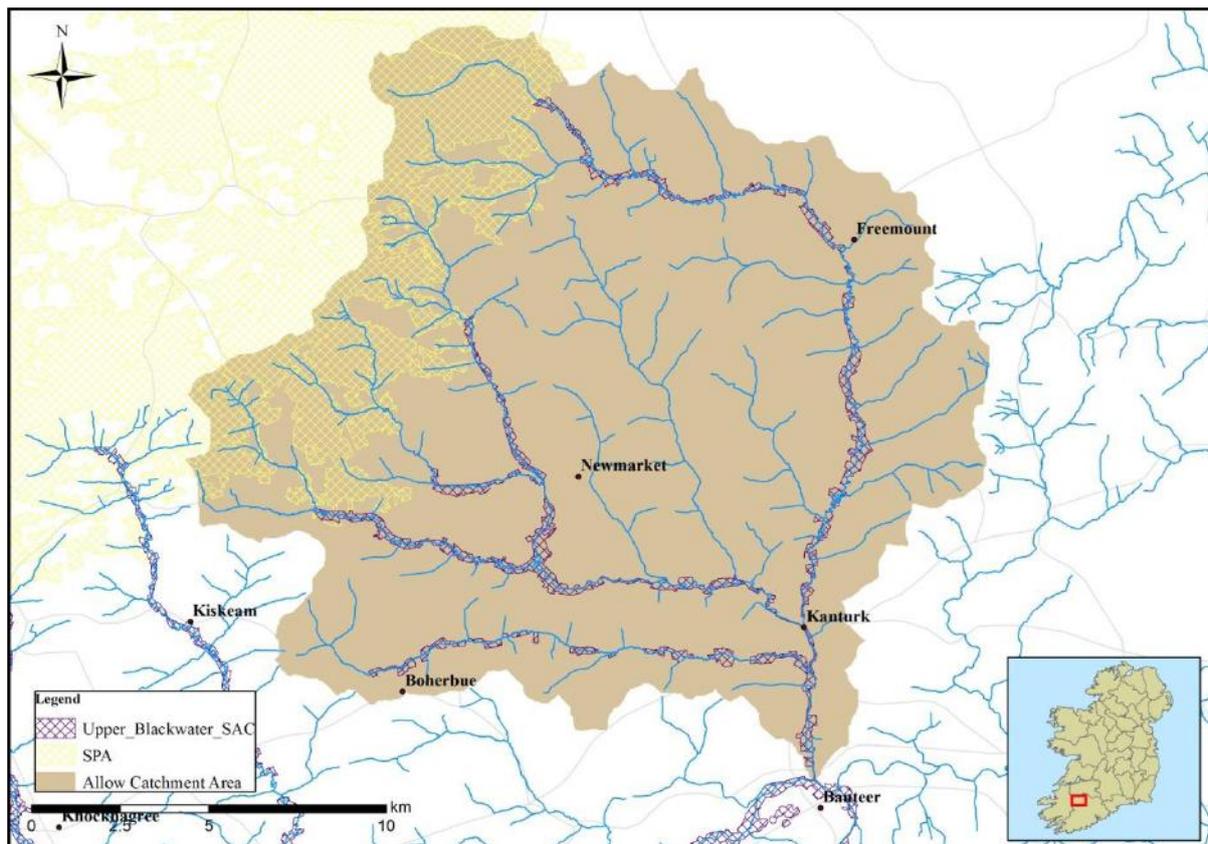


Figure 1 River Allow catchment area

The River Allow drains a catchment of 310km² (Figure 1). The three major rivers occur within the catchment; Rivers Allow, Dalua and Brogeen. The main agricultural land use in the catchment is pasture for dairying and suckler cattle.

The majority (70%) of the soils in the Allow catchment are deep, poorly drained mineral soils. Blanket peat covers approximately 5% of the catchment, mostly in upland reaches. Mineral alluvium is associated with the river channels, while shallow well drained mineral soils make up the remaining soil type in the catchment (EPA/Teagasc, 2006; Tedd, 2014).

The rivers within the River Allow catchment (Allow, Dalua, Brogeen, Glenlara and Owenkeale) form part of the Blackwater River (Cork/Waterford) Special Area of Conservation (Natura 2000 site code: 002170). These tributaries provide important habitat for Freshwater Pearl Mussel *Margaritifera margaritifera*, Atlantic salmon *Salmo salar* and European otter *Lutra lutra*, all of which are listed in the Annex II of EU Habitats Directive.

The upper reaches of the Allow catchment drains the Stacks to Mullaghareirk Mountains, West Limerick Hills and Mount Eagle Special Protection Area, which is designated for Hen Harrier *Circus cyaneus* (Annex I of the EU Bird's Directive).

Methods

Planning and Monitoring

Planning the logistics of the *I. glandulifera* control programme required a detailed survey of the distribution of the plant infestation in the catchment. Walk over surveys were conducted in Spring 2011 concentrating on areas where known infestations occurred to determine ontogenetic development of the plant.

Plants began to emerge in April 2011. Once plants were sufficiently developed to be differentiated from the background vegetation (>10cm high), training exercises were organised for Rural Social Scheme participants, project staff and volunteers. A trial site was also established in Newmarket to track development of the plant over a single growing season (this is explained in more detail below).

Maps of the entire river system were produced using satellite imagery from Google Earth and augmented by aerial photographs of the catchment taken by Inland Fisheries Ireland and the Irish Air Corps in June 2011. Surveyors were asked to mark on the map where infestations occurred and rank the infestation density according to an arbitrary scale developed based on initial density estimates at the *I. glandulifera* trial site in the grounds of the James O'Keeffe Institute, Newmarket.

After onsite training, walk over surveys were conducted using teams of up to 8 personnel assigned to each river bank to maximise coverage of the survey and avoid omission of any infested area. These walkover surveys were also conducted from within the channel, to identify plants growing out of the river banks, mid channel on islands etc. or along the wetted perimeter. Riparian areas, the flood plain and adjacent field drainage networks, adjoining fields and road verges were walked systematically. Areas of high infestation were marked for immediate attention, access points noted, and areas with difficult access highlighted. Surveys commenced at the confluence with the Blackwater River following the infestation upstream to the eventual source.

Once the survey work was completed, the data was mapped into GIS. Access points were noted and the logistics of the control operation planned. Riparian land owners were then identified through the land registry and through local contacts (not all landowners were listed accurately on the registry). A notice was sent to each landowner, outlining the LIFE project, the rationale

behind the proposed invasive species control operation, what was involved, and their permission was sought. This was followed up with a phone call. If landowners had concerns a face to face meeting was organised. Public meetings were also held to outline the overall project and project updates were given through the project newsletter and educational lectures.

Monitoring of Himalayan balsam control

To determine the effectiveness of the control programme, a network of 22 quadrats (1m²) was established along the River Allow. These quadrats were located at intervals (determined by access) along the channel reach, within dense stands of *I. glandulifera* (reflective of the occurrence of *I. glandulifera* at these particular points) from Kanturk Town to the confluence of the River Allow and River Blackwater. The quadrats were located for the most part within the riparian area adjacent to the river, which is prone to flooding and where some of the heaviest infestations were noted. Assessments were carried out on an annual basis (2011 (initial survey), 2012, 2013, 2014 and 2015). Not all quadrats were accessible on every survey occasion due to varying water conditions (especially in 2013 where inclement weather delayed the survey date).

At each quadrat location a list of plant species and an estimate of the percentage cover of vegetation was taken. The percentage cover values were assigned by plant group, i.e. grasses or broad-leaved herbaceous plants. The percentage of bare ground was also recorded. A note was taken on the degree to which the location was shaded (open/partly shaded/shaded), as well as any relevant site management e.g. grazing, herbicide application.

A final walkover survey of the entire river was conducted in 2015, to establish the success of the treatment programme. A photographic record was also kept for subsequent analysis and verification by a specialist botanist.

Trial site (Newmarket): Characterisation of Himalayan balsam in Duhallow

The source of *I. glandulifera* in the River Allow catchment was identified on April 3rd 2011. The infestation covered an area of 550m². It was found to be located in a disused composting area on the grounds of the James O'Keeffe Institute, along the banks of a tributary of the Rampart River (a tributary of the River Dalua). This site is located at the base (south-western end) of the Newmarket Community pitch and putt course. Anecdotal information from a former resident (a nun from the Order of Sisters of St. Joseph) indicates that the plant was grown in the Newmarket Demesne as an ornamental plant in the 1950's.

A series of trial plots were established at this site to examine the growth characteristics of *I. glandulifera* in Duhallow. In order to obtain a better understanding of the densities and growth characteristics that *I. glandulifera* can achieve in the geographic area (i.e., North Cork), and the potential impact that it can have on native vegetation, 1m² quadrats were examined at regular time intervals (normally biweekly basis). The following attributes were determined: the number of plants per quadrat, the length of plant at discrete time intervals, the number of leaves per plant and later in the 2011 growing season the number of flowers per plant. An assessment of the native species composition was also determined. At each time interval *I. glandulifera* was removed from a quadrat whilst the surrounding *I. glandulifera* plants were allowed to continue to grow. A new quadrat was established at a different location within the stand, every fortnight throughout the growing season.

The results of this study helped to establish the basis for the subsequent categorisation of *I. glandulifera* densities mapped along the River Allow catchment, prior to the commencement of the removal programme in 2011.

Treatment method

A range of methods are recommended for the treatment of *I. glandulifera* (Invasive Species Ireland, 2015; Inland Fisheries Ireland, 2015; Cabi, 2015). The method trialled in the IRD DuhallowLIFE project was manual removal by teams of people walking the riparian areas within the catchment, physically pulling the plant. Removal was done entirely by hand, as it was found to be unnecessary to employ machinery for this task. Plant identification training classes were organised for Rural Social Scheme participants. Participants were trained in how to correctly identify *I. glandulifera*, including how to recognise young plants, and how to correctly remove the plant.

I. glandulifera are annual plants growing from seed each year. Germination normally occurs in April and growth is rapid once the plant becomes established. Removal commenced once the newly emergent plants were distinguishable from the surrounding vegetation and were at a height suitable for manual pulling (>10cms). A botanist was employed on request from NPWS to assess the project area, and ensure that there were no EU Habitats Directive Annex II listed plants or plants of national importance within the treatment zone, that could be inadvertently removed or damaged. Crews of up to eight people worked together following maps provided, taking care to remove *I. glandulifera* whilst avoiding any unnecessary trampling or damage to other riparian plants or features.

Disposal of plant material

During the first year of operation (2011), all plants removed were retained in 50kg fertiliser bags. Initially, it was planned to dispose of the plants in a licensed landfill for invasive species. However, this proved to be impractical and transport of material a potential biosecurity hazard. A trial was carried out whereby the plants were contained in an area lined with plastic, and the plants allowed to rot down into a slurry. This was found to be very effective and the material was found not to be viable once the slurry had formed.

However, this was found to be impractical due to the volumes involved in the collection of the material (e.g., one day's removal could result in volumes of material in the excess of 50m³ to be disposed of). Thus the project adopted a strategy of retaining the pulled plant onsite but ensuring that it was not viable. Roots were removed and where flower heads had appeared these were also removed. Advance stage plants with seed heads were avoided by routine RSS crews. To remove these plants a team trained in the control of advance stage plants was deployed. This team placed small 1litre transparent bags around the seed pods, making sure not to disturb adjacent pods. Once the pods were enveloped within the bag, the stem was cut and the seed head removed. This was found to be an effective, albeit slow method to treat advance stage plants. Bags were collected and the seeds heads were disposed as described or burnt. Operators carefully checked and brushed down each other's clothing prior to leaving the site to ensure to avoid inadvertently transporting seeds off site. It was estimated (based on 2011 on site observations) that up to 70% of seeds produced by a plant could be removed in this manner.

Relationship between plants growing in open sunlit areas and closed canopy shaded areas

Field surveyors and invasive species control crews noticed that there were significant on the ground variations in the development stages of *I. glandulifera* plants depending on the habitat where they occurred. Generally, it was observed that flowering (early June onwards) occurred earlier in plants growing in sunlit open field sites. Plants growing in more shaded locations and sharing space with other plants especially larger woody vegetation such as willow or alder, tended to flower later (July onwards). In heavily shaded areas, commencement of flowering did not begin until late August or early September. To examine this anecdotal observation further, the stage of development of plants growing under three conditions (open sun lit site, damp shaded site and dry shaded site) were examined. Ground wetness was also examined as

a variable as field staff believed that this may also have been relevant (Appendix 1: Figures 12 & 13).

Results

Initial walkover surveys determined the extent of the Himalayan balsam (Figure 2).

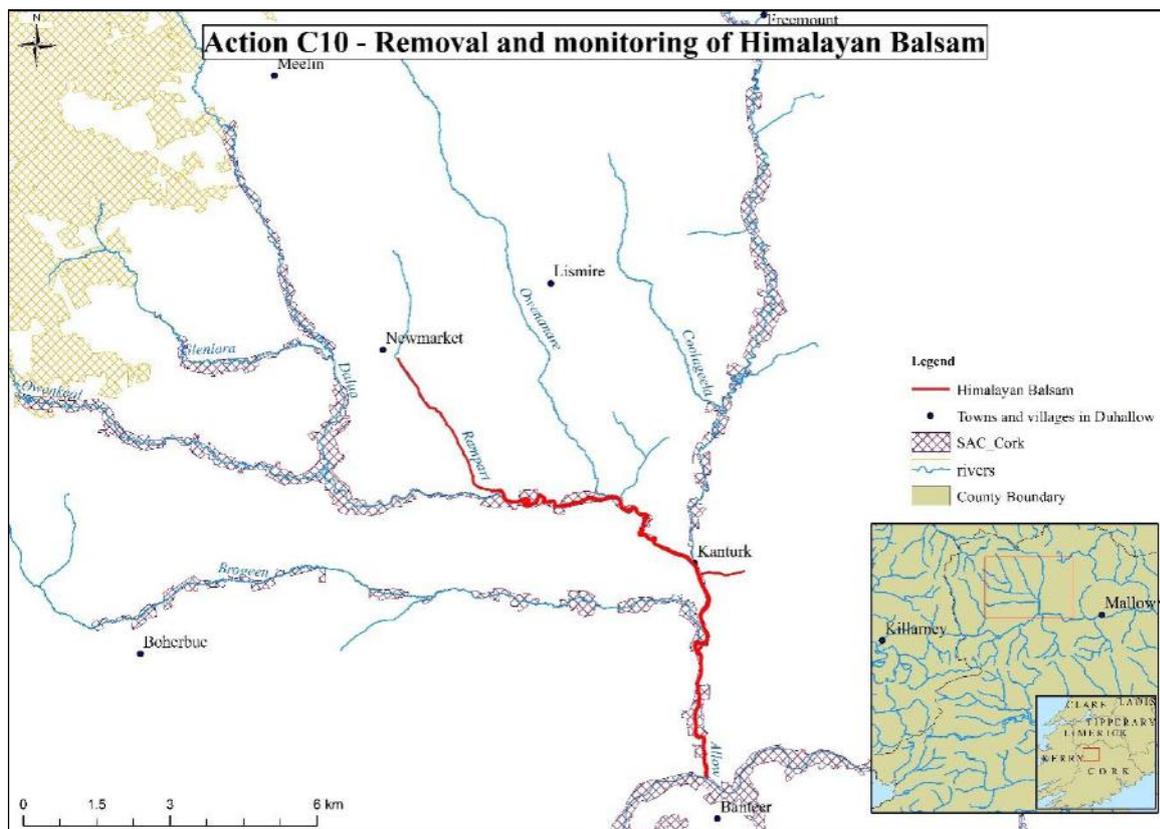


Figure 2 Extent of *I. glandulifera* determined from walkover surveys conducted in 2011

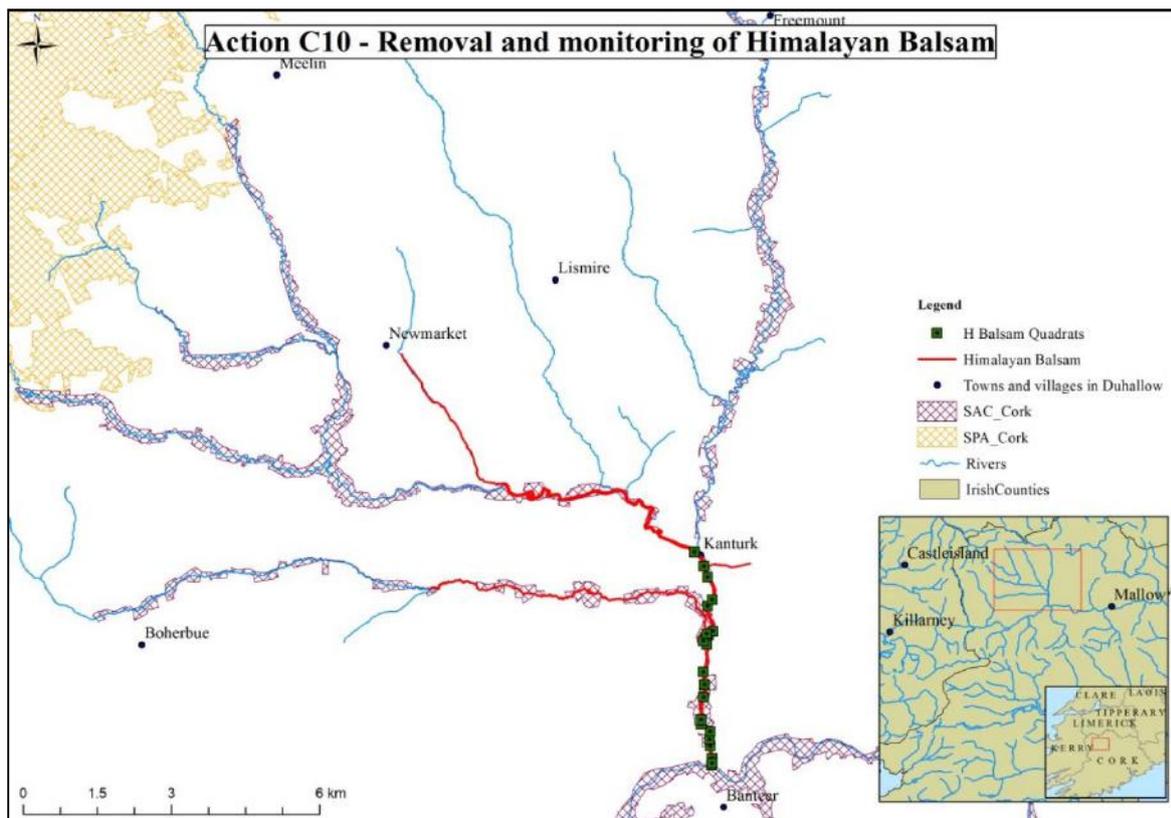


Figure 3 Extent of *I. glandulifera* infestation in Allow River catchment and locations of monitoring quadrats

The key features of the results outlined below are (i) the low level of regrowth of *I. glandulifera* in removal sites and (ii) the rapid recovery of native riparian vegetation at those sites. In 2015, 21 of the 22 monitoring sites had no regrowth of *I. glandulifera*. The plant was found at Q20 only, with 15% cover (2 plants).

All of the sites showed excellent recovery of native vegetation. Subjective visual appraisal of the monitoring sites indicated that removal of the invasive plant had a positive effect on native riparian vegetation. This finding is supported by the results of the quadrat analysis in Tables 1 and 2 and Figures 4, 5, 6, and 7 below. The charts in Figures 4-7 show quite clearly the change in vegetation cover before and after removal of *I. glandulifera*. Most of the quadrats had complete cover of native vegetation within one year. These tended to be the plots in open sunlit conditions.

Shaded habitats were slower to respond to the removal of *I. glandulifera*, where the high proportion of bare ground can be at least partly attributed to the low light conditions and, in some cases, grazing and poaching by livestock.

Quadrat 19 contained a relatively high proportion of bare ground and in 2015 had been partially colonised by the non-native invasive species Japanese knotweed *Fallopia japonica*.

Apparent fluctuations in average percentage cover between grasses and herbs/shrubs between years may be affected by several factors including grazing pressure, plant competition, and differences in recording season and number of plots recorded in any one season.

Table 1 Average cover of different plant groups in monitoring quadrats 2011-2015

Year	Himalayan Balsam	Grasses	Broad-leaved herbaceous plants	Bare ground
Average % cover in 2011	64	24	22	56
Average % cover in 2012	0	71	41	9
Average % cover in 2013	0	46	44	11
Average % cover in 2014	0	51	44	8
Average % cover in 2015	0.7	55	45	3

Table 2 *I. glandulifera* occurrence in monitoring quadrats: 2011 (May- July), 2014 (September) and 2015 (June).

Quad	Area of stand (m ²)	No. H. Balsam per m ² (2011)	No. H. Balsam per m ² (2014)	No. H. Balsam per m ² (2015)
1	76	220	0	0
2	16	48	0	0
3	18.4	138	0	0
4	52.5	62	0	0
5	80	184	0	0
6	0	0	0	0
7	143	144	0	0
8	115.2	72	0	0
9	360	74	0	0
10	540	136	0	0
11	64.4	30	0	0
12	74.9	70	0	0
13	87	132	0	0
14	24	43	0	0
15	15	181	0	0
16	680	41	0	0
17	449.8	30	0	0
18	90.5	80	0	0
19	3750	73	0	0
20	296.6	61	0	2
21	266.5	91	0	0
22	252.7	88	0	0

When the average percentage cover values for grasses and herbaceous species are separated, there is some indication of a fluctuation in cover between these two groups from 2012 to 2015. The data indicate that grasses responded most strongly to *I. glandulifera* removal in the first year, with a proportionally high average percentage cover (71%) when compared with broadleaved herbaceous species (41%). In subsequent years the proportion of grasses to herbs was roughly equal.

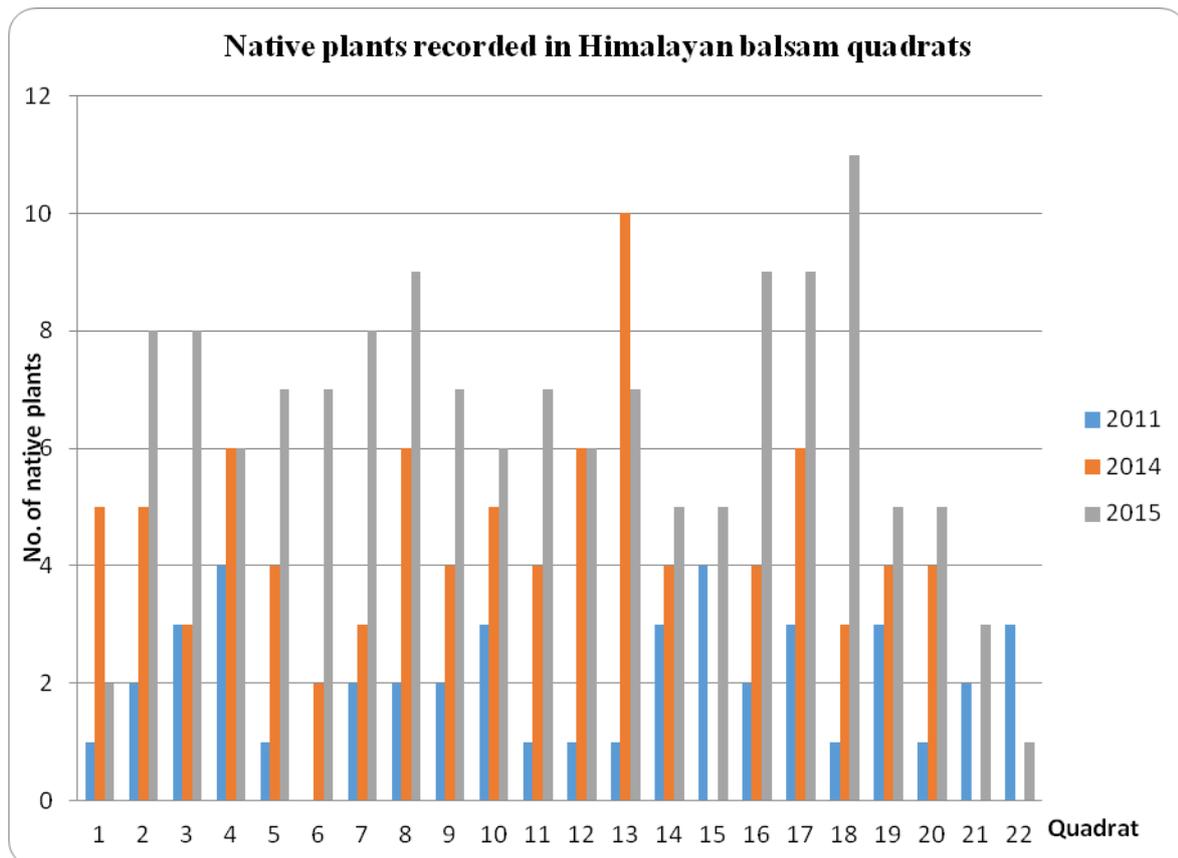


Figure 4 Native species richness recorded within 22 quadrats along the Allow River. Species recorded in 2011 are pre-management of *I. glandulifera*. Note: Quadrats 15, 21 and 22 were not surveyed in 2014 due to inaccessibility at the time of surveying.

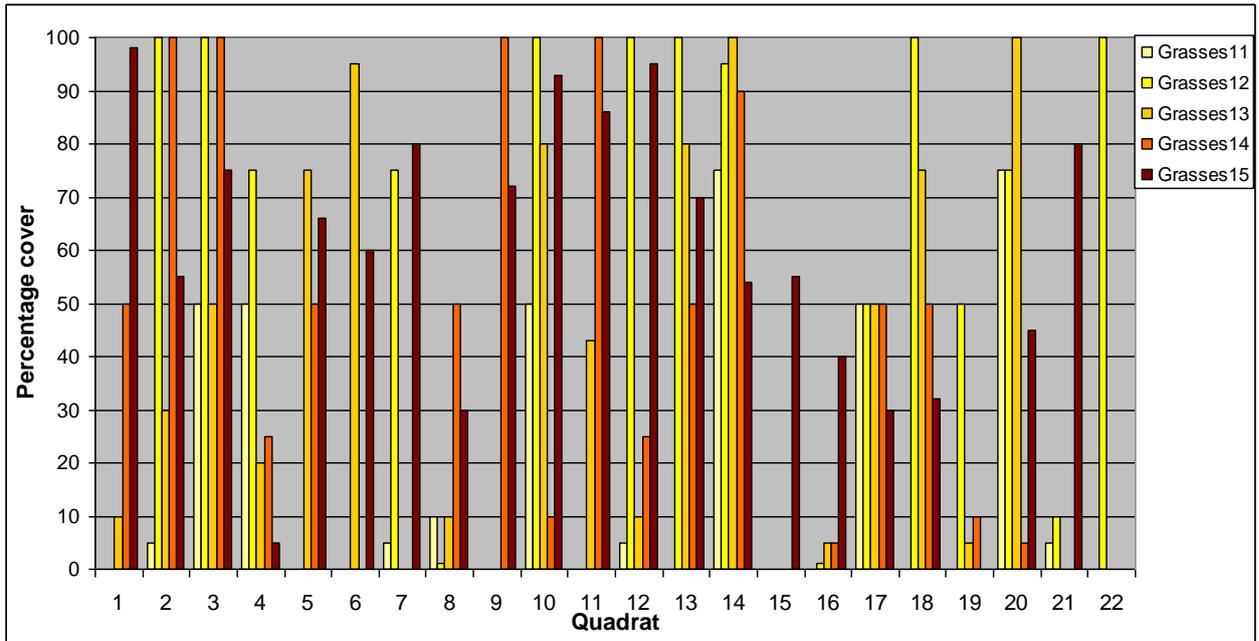


Figure 5 Percentage cover of grasses in monitoring quadrats 2011-2015

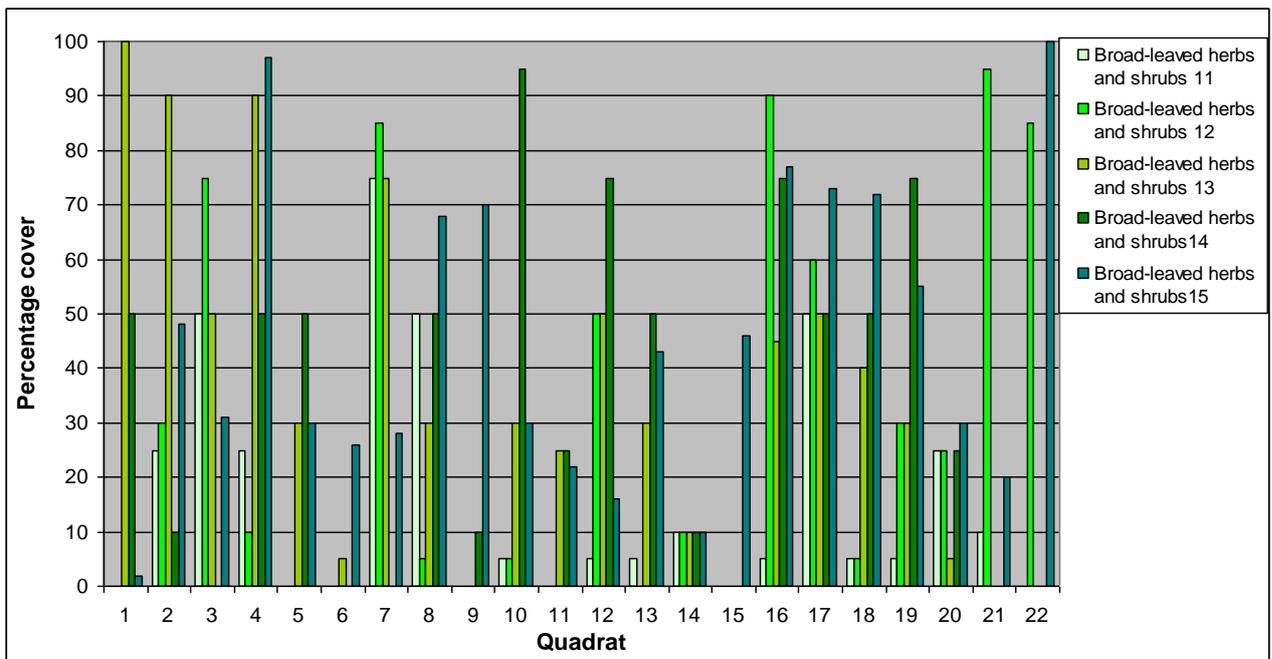


Figure 6 Percentage cover of broadleaved herbaceous species and shrub species in monitoring quadrats, 2011-2015

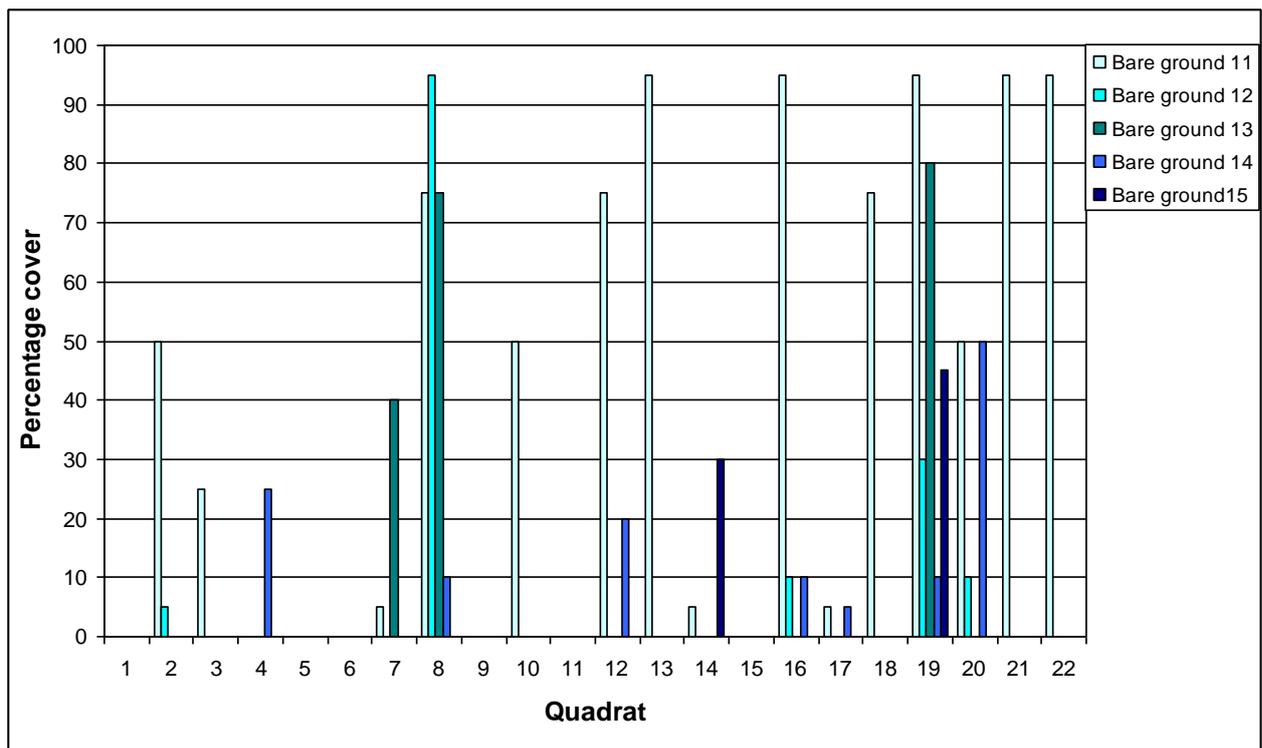


Figure 7 Percentage cover of bare ground in monitoring quadrats, 2011-2015

Vegetation recorded in the quadrats tended to be dominated by a small number of grass and reed species, particularly reed canary-grass *Phalaris arundinacea*, bent-grasses *Agrostis* spp. and meadow-grasses *Poa* spp., with occasional Yorkshire fog *Holcus lanatus*, meadow foxtail *Alopecurus pratensis* and scutch *Elymus repens*.

Broad-leaved herbaceous species tended to be dominated by those indicating nutrient-rich conditions, particularly nettle *Urtica dioica*, docks: broad-leaved *Rumex obtusifolius* and clustered *R. conglomeratus*, creeping buttercup *Ranunculus repens*, cleavers *Galium aparine*, common hogweed *Heracleum sphondylium*, bindweed *Calystegia sepium* and cow parsley *Anthriscus sylvestris*. Hemlock water-dropwort *Oenanthe crocata* was frequent. Where bare muddy areas are naturally exposed by low water in summer, bistorts *Polygonum* spp. dominated the vegetation. Other wetland species were found occasionally to rarely, such as silverweed *Potentilla anserina*, watercress *Rorippa* sp. and iris *Iris pseudacorus*. Shaded areas contained occasional plants of wood avens *Geum urbanum* and false brome *Brachypodium sylvaticum*. Bramble *Rubus fruticosus* agg. occurred frequently in both shaded and less shaded habitats.

Conclusion

Figure 2 gives an overview of the distribution of *I. glandulifera* in the catchment (Rivers Allow and Dalua) determined in the 2011 surveys. The range of the invasive plant was found to be substantially greater than that recorded in the original survey, which was conducted in 2009 in preparation of the EU LIFE application. The 2009 survey, was a preliminary survey, and only identified *I. glandulifera* on the River Allow downstream of Kanturk town (5km, approximately). However subsequent survey work 2011 survey found that the infestation extended upstream of Kanturk town. *I. glandulifera* was also identified by surveyors along the River Dalua, upstream of the River Dalua along the Rampart River to the source of the infestation in Newmarket. No balsam was noted along the River Allow main channel, upstream of Kanturk town. However, a small stand was identified and removed from an adjacent forestry plantation near Freemount village (12km upstream of Kanturk). Figures 9, 10 and 11 show the locations of high densities of *I. glandulifera* recorded in 2011 and how these densities have fallen significantly over the four years of continuous management.

In 2013 survey work on tributaries of the upper Blackwater River for Action A3, identified approximately 6.1km H balsam within a 7.4km stretch River Brogeen, a tributary of the River Allow. Invasive species removal crews were directed to this tributary to remove the plant. This was strictly an eradication exercise, as sufficient monitoring was already taking place on the River Allow and resources were not available to set up an additional monitoring area. The Brogeen River was walked in 2015 by both the LIFE team and anglers to determine the efficiency of the control programme.

The density of *I. glandulifera* along discreet reaches were estimated by surveyors on the initial walkover surveys. Large densities occurred along stretches of the River Dalua, upstream of Kanturk town. These were often associated with depositional areas within the flood plain including ox bow formations and depressions coinciding with historic channel routes. These coincided with typologies identified on GIS maps. It is evident that large concentrations of seeds were deposited in these areas as water levels receded post flood events. Large stands were also noted on the River Allow, again associated with areas prone to flooding. *I. glandulifera* is very opportunistic and was found growing across a broad range of substrates, including earthen banks, in river gravel deposits, fine silt deposits in flood prone areas, on rotting straw bales in fields and even growing on the limbs of trees crossing the river.

The coverage of *I. glandulifera* on the riverbanks of the Allow, Dalua and Brogeen rivers has been significantly reduced since the implementation of the DuhallowLIFE project.

The findings from the vegetation monitoring aspect of the project demonstrate clearly the effect that monospecific stands of *I. glandulifera* have on native riparian vegetation and seem to back previous findings (Hulme & Bremner 2006) that ruderal vegetation communities, dependent on high light conditions, are most affected by invasion by dense stands of this species. Hulme and Bremner (2006) found an increase in other non-native plant species where Himalayan Balsam had been removed. This effect was observed at one location in the Duhallow study area, quadrat 19, where Japanese knotweed had become established in the plot.

The low diversity of species recorded following removal is indicative of the nutrient-rich conditions of the catchment in the study area and is typical of the types of riparian habitats found in the project area. The findings of this study suggest that in these types of riparian habitats and nutrient conditions, grasses will initially respond more vigorously to *I. glandulifera* removal. In general, the areas from which the plant was removed have returned to a grassy sward dominated by a few robust species which thrive on the nutrient-rich alluvial soil.

During the progress of the project it was discovered that *I. glandulifera*, once pulled, could be left to desiccate on dry ground. In damp conditions however it was found that the pulled plant would regenerate and take root from its nodes. Helmissaari (2010) reports that *I. glandulifera* has the ability to regenerate and new branches and even flowers can form along the stem of a plant recently removed. The findings of Ruckli *et al* (2014) on the effect of allelochemicals produced by *I. glandulifera* implies that removal from site of plant material pulled as part of a control programme could contribute to more rapid native vegetation recovery.

I. glandulifera produces more flowers in the open than in shaded areas. Dry shaded areas in turn produced more flowers than damp shaded areas. In fertile soils with sufficient natural light *I. glandulifera* can eliminate perennial vegetation. In shaded and less fertile sites the plant is less likely to totally out-compete other perennial species (Sanderson, 2013). The slower recovery of vegetation in shaded habitats seen in this project may be at least partly attributable to localised grazing and poaching by livestock.

Lessons learnt

I. glandulifera is an invasive plant species that can colonise riparian areas very rapidly using water as a transmission vector. Once it becomes established along a river reach it can rapidly colonise sections downstream of this point as the seeds float on water. Its ability to project seeds from ripe pods facilitates the upstream, albeit slower (estimates suggest up to 7m/annum) spread and lateral spread of the plant. Other vectors include wildlife, livestock farm vehicles (a major issue increasing the risk of transfer to other areas is from farm machinery brought to the river to collect water or for activities such as fencing). Users of riparian areas for recreational activities, including walking and angling, pose a risk of transfer of seed which may stick to clothes, falling off later. The project found that anglers were the most aware of the above groups and generally took some precautions to prevent transfer.

This project demonstrated that it is possible to remove *I. glandulifera* from large spatial areas, such as river reaches, if planned appropriately with adequate resources and strategic planning. Manual removal by hand is sufficient and there is no need for chemical applications. Repeat visits were essential as plant germination was noted throughout the growing season. Plants germinated and flowered as late as October. It is assumed that these plants germinated from dormant seeds that became activated by sunlight once shading by other *I. glandulifera* plants was removed.

Transferability

The project established that manual removal of *I. glandulifera* by hand is an effective method to remove this plant from riparian areas. The scale of the work carried out, shows that it is possible to remove *I. glandulifera* from large areas and it is recommended that this is done along SACs in particular. The earlier that this work is done, once colonisation has been identified the better, as less resources will be required compared to treating established infestations.

In general, for rivers, it is recommended that the removal work should commence at the source of the infestation. However, for larger projects, it is recommended that the time of flowering onset is established and characterised throughout the project areas, and crews are directed to areas where early flowering may occur (e.g., open riparian areas, marshy areas or field margins) to maximise efficiency or resources. Crews can then be mobilised to areas where plants mature later such as areas heavily shaded by overhead tree canopy. It is important that areas cleared

earlier on in the year are regularly revisited by smaller crews to remove any plants missed first time round or where new plants have germinated.

It is recommended that plants are removed prior to flowering. The roots should be removed and the plant stem broken into sections reducing the likelihood of new roots forming. Where large stands are present, it is recommended to stack the plants into piles as it makes it easier for monitoring and addressing any potential regrowth. Plants in flower can also be removed but the flower head must be removed to avoid the seed pod developing.

Once plants within a stand have started to flower, plants should be removed quickly before it goes to seed. It is possible to treat plants that have gone to seed, but there will inevitably be some seed loss and a careful biosecurity arrangement needs to be put in place to avoid the accidental dispersal of seeds from the site by the operators. A simple method to remove plants in seed is to place a small plastic bag over a cluster of seed pods, closing the bag along the stem and twisting off the plant. The seeds will pop on contact with the side of the bag but at that stage will be contained. Great care is needed not to trigger the pods prior to placement of the bag and not to disturb other pods on the plant or adjacent plants. Therefore, only careful operators should attempt this task. It is effective however and the DuhallowLIFE project estimated that up to 70% seed removal can be achieved this way.

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Appendix 1 Control and Management

Location: River Allow, Creamery, Kanturk town, (ITM: 538241,603033)



Location: River Allow, Adjacent to soccer field, Kanturk town, (ITM: 538372,602029)



Location: River Dalua, Dalua Bridge, Kanturk town, (ITM: 538091,603225)



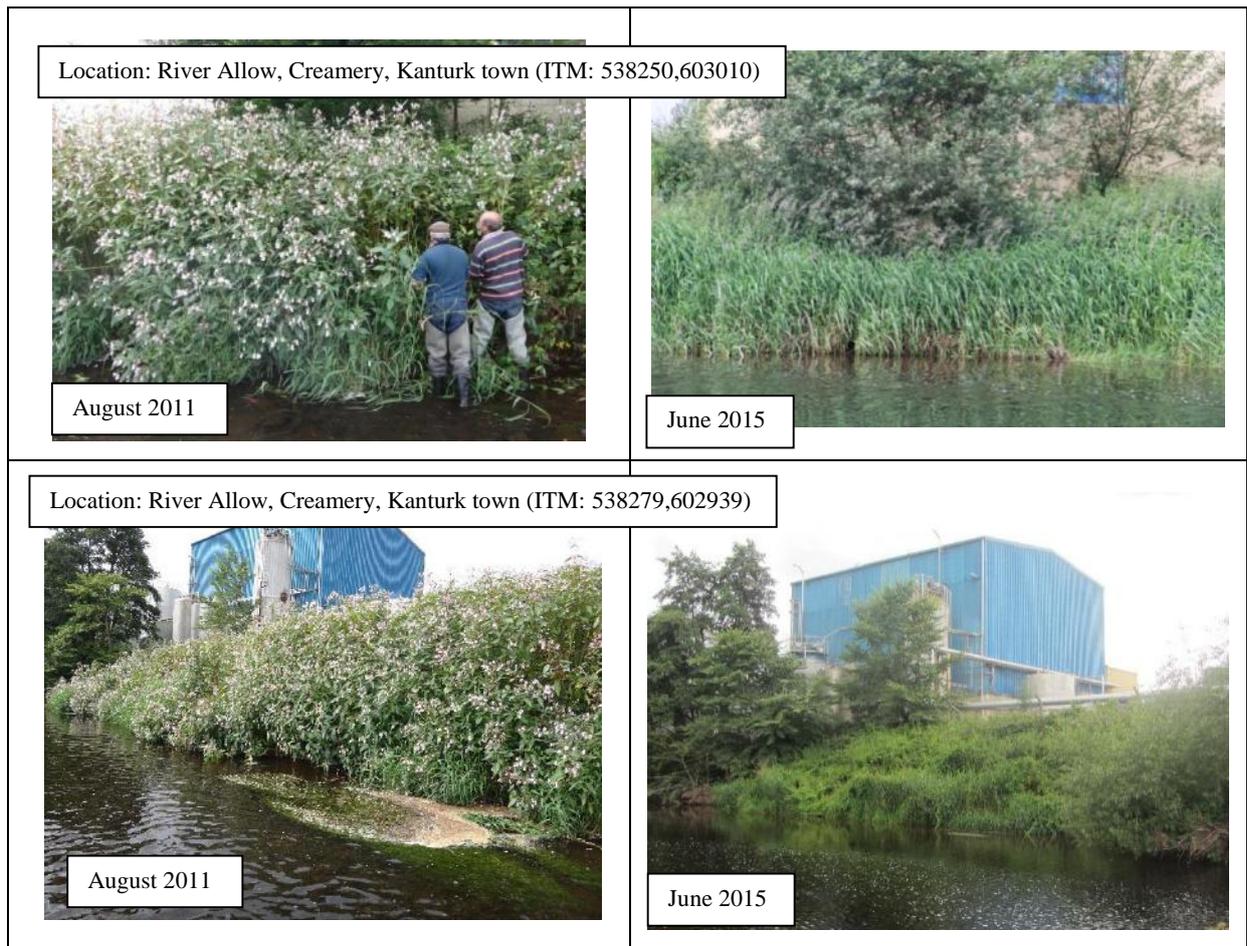


Figure 8 Before and after photographic evidence of successful Himalayan balsam management along the Allow and Dalua Rivers

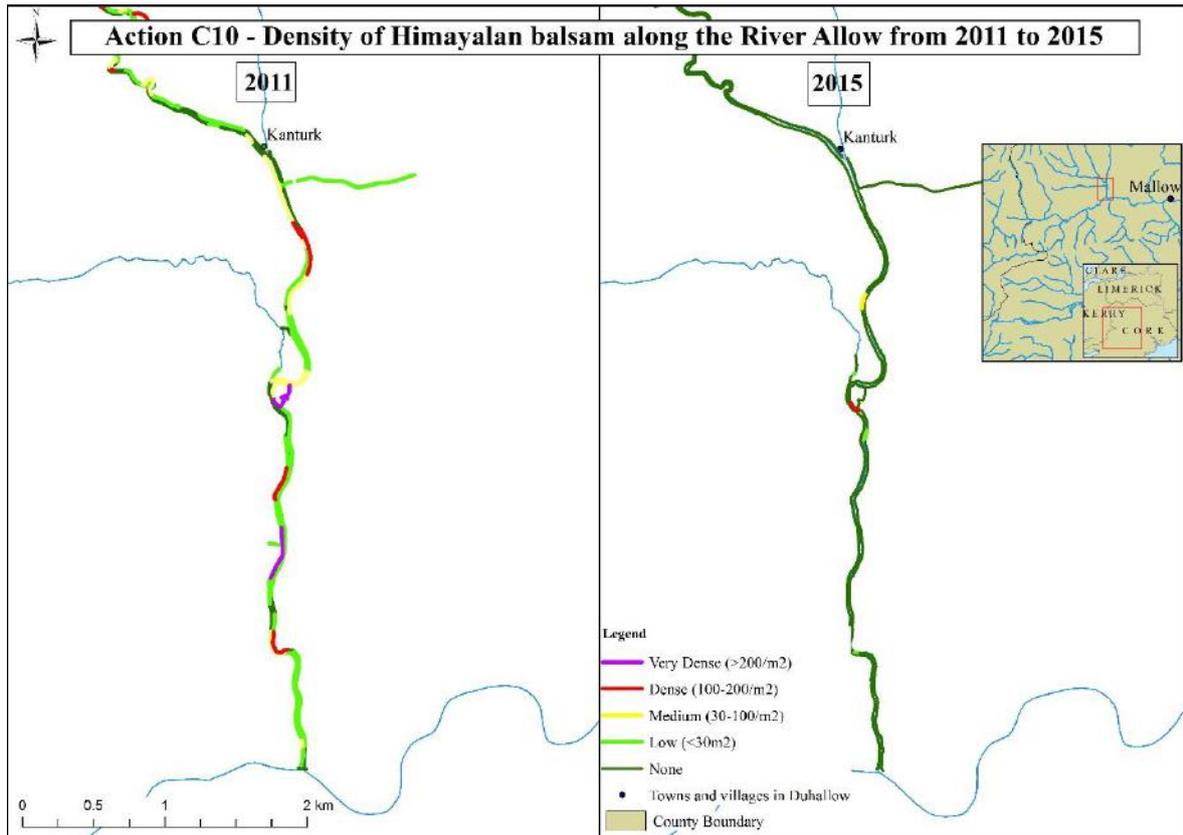


Figure 9 Recorded distribution and densities (mean number of plants/m²) of *I. glandulifera* along the River Allow in 2011 and 2015

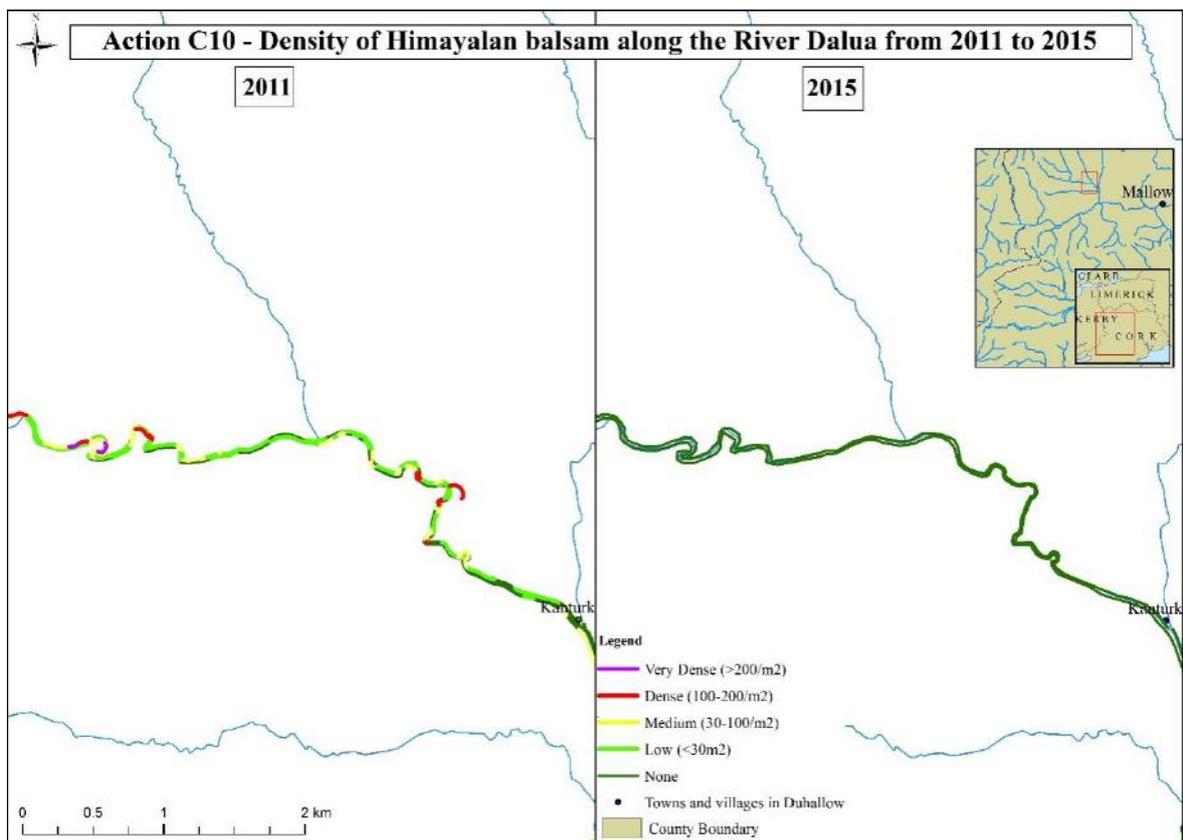


Figure 10 Distribution and densities (mean number of plants/m²) of *I. glandulifera* along the River Dalua in 2011 and 2015

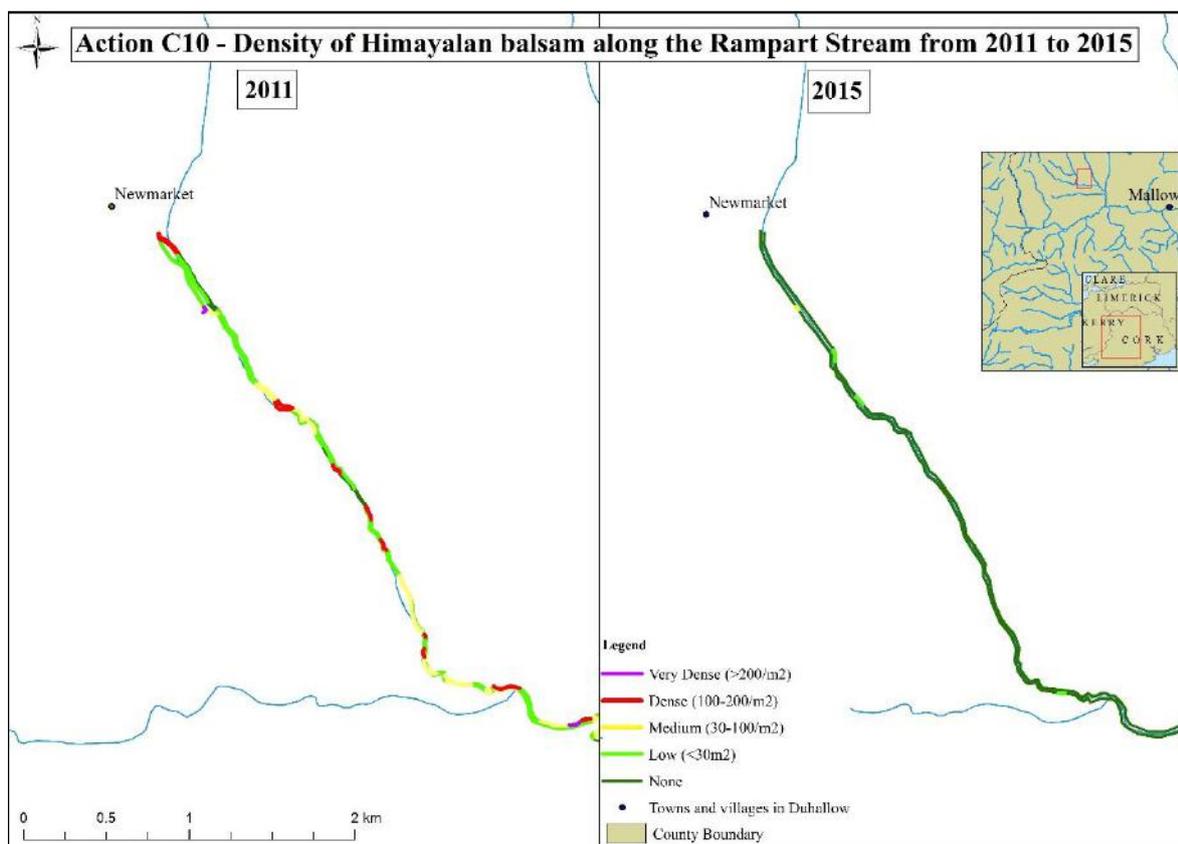


Figure 11 Distribution and densities (mean number of plants/m²) of *I. glandulifera* along the Rampart Stream in 2011 and 2015

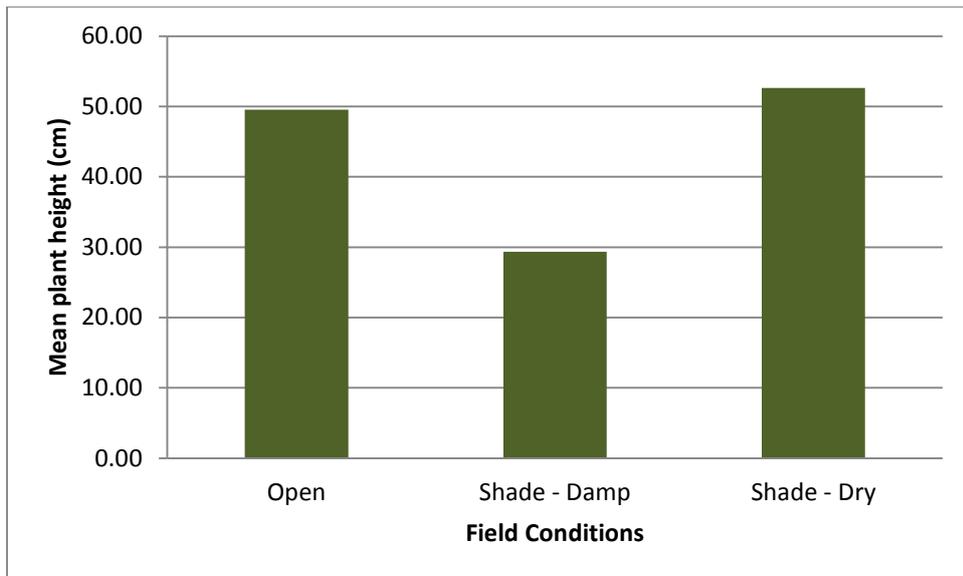


Figure 12 Mean heights of *I. glandulifera* recorded in three different field conditions: open ground (n=26; ITM: 532354, 606901), in damp shaded (n=26; ITM: 532080, 607351) and dry shaded (n=26; ITM: 532103, 607288). Trial site was located in Newmarket.

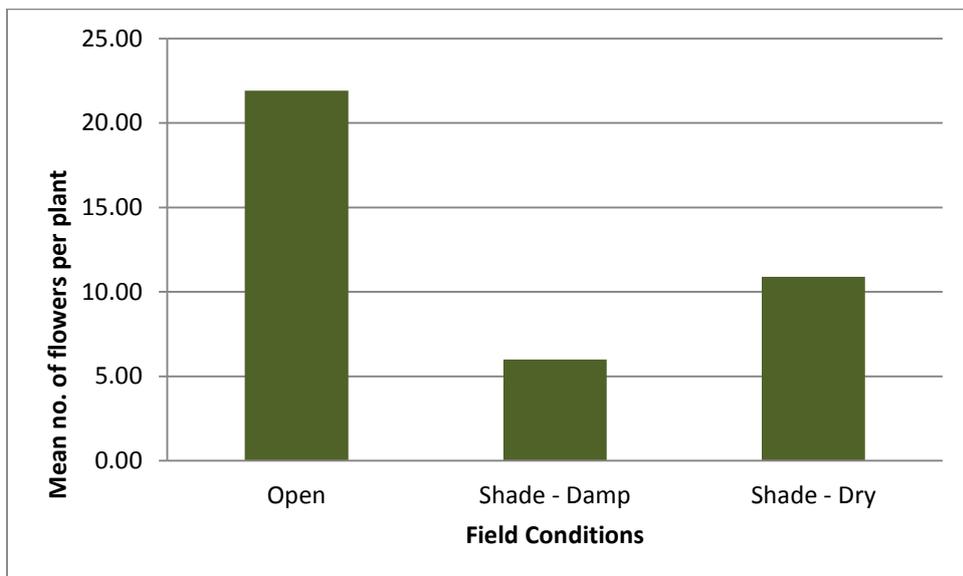


Figure 13 Average number of flowers per plant counted on *I. glandulifera* plants in three different field conditions: open ground (n=26; ITM: 532354, 606901), in damp shaded (n=26) and dry shaded (n=26). Trial site was located in Newmarket.