Impact of INNPS Control for the Ayrshire Rivers Trust

1. Purpose:

The purpose of this report is to present and describe the extent and impact of work undertaken for the control and attempted eradication of riparian invasive non-native plant species (INNPS) in the Ayrshire Rivers Trust (ART) area. ART received funding through the Interreg IVA controlling priority invasive non-native riparian plants and restoring native biodiversity (CIRB) project. This is a cross border project with the lead partner being Queens University Belfast and others including Rivers and Fisheries Trust Scotland (RAFTS), Galloway Fisheries Trust, Argyle Fisheries Trust, Tweed Forum and Inland Fisheries Ireland. 75% of the fund was received from Interreg IVA with the remaining 25% coming from each of the local councils; South Ayrshire, North Ayrshire, East Ayrshire, and the Scottish Environment Protection Agency (SEPA) restoration fund now known as the water environment fund (WEF).

2. The Initial Situation:

Description of the ART area

There are six major catchments within the Ayrshire Rivers Trust area: the Garnock, Irvine, Ayr, Doon, Girvan and Stinchar. There are also a number of smaller coastal burns flowing directly into the Firth of Clyde. Within the area covered by Ayrshire Rivers Trust[1] there are four District Salmon Fishery Boards, serving the Stinchar, Girvan, Doon and Ayr. Land use within the six major Ayrshire river catchments is detailed in Figure 1 below.

The **River Garnock** is the smallest of Ayrshire's rivers at 39 km in length and with a catchment size of 238 km^2. Its major tributary is the Lugton Water. The average flow is 8.1 m^3/s and it joins the sea in an estuary it shares with the River Irvine. The dominant land uses in the catchment are agricultural, moorland and urban development. It contains low forestry cover and 74 % of the land is improved, or good rough grassland.

The **River Irvine** has the second largest catchment in Ayrshire with an area of over 380 km^2. The river itself is 42 km in length. The River Irvine has been highly modified with urban development. There are many tributaries including the Annick Water, Cessnock Water and Glen Water. Agriculture, forestry and urban development are the main land uses. Water quality is negatively affected by diffuse pollution pressures within the catchment area. The Irvine has the highest human population density of all the Ayrshire catchments and the second highest human density of any salmon river in Scotland, after the River Clyde.

The **River Ayr** is the largest river in Ayrshire with the main stem measuring over 63 km. The catchment incorporates 574 km^2, with a number of major tributaries including the Greenock Water, Lugar Water, Water of Fail and Water of Coyle. It has an average flow of 16 m^3/s. The principal land uses are agricultural, forestry and mineral extraction, with a concentration of dairy farms in lowland parts of the catchment. The river passes through many towns and villages and contains three Sites of

[1] (Note. The Water of App is an Ayrshire river. Management for this watercourse however, is currently the responsibility of Galloway Fisheries Trust and for this reason the App catchment has been excluded from the Ayrshire Biosecurity Plan)

Special Scientific Interest (SSSI). The Ayr catchment is also one of the main areas in Scotland for opencast coal mining.

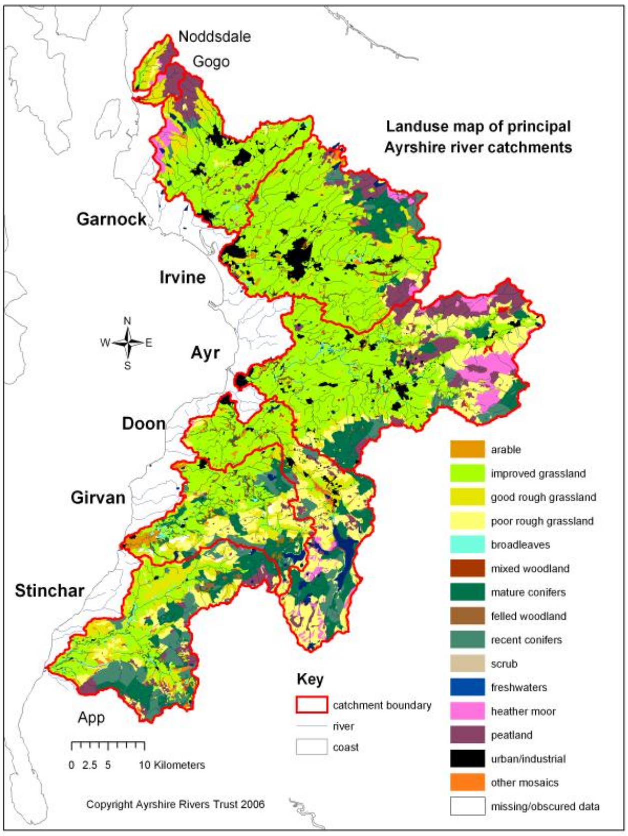

Figure 1 Map showing the principal land use in the area of the Ayrshire river catchments

The **River Doon** stretches for a distance of 58 km including Loch Doon. Loch Doon is dammed to store water for the Galloway Hydro-Electric power scheme. The river itself starts below the dam with a steady compensation flow of 45 million gallons/day. The catchment area is 324 km^2 and the river runs past several villages including Dalmellington, Patna and Dalrymple. The River Doon supports a number of species of interest to biodiversity conservation with populations of freshwater pearl mussels (*Margaritifera margaritifera*) and Saucer Bugs (*Aphelocheirus aestivalis*). There are four SSSI's within its catchment: Loch Doon, Ness Glen, Bogton Loch and Dalmellington Moss. In the lowland parts of the catchment the dominant land use is agricultural, with extensive areas of rough grazing and conifer plantations in the higher altitude areas.

The **River Girvan** is approximately 40 km in length with a catchment area of 250 km^2 and an average flow of 6.1 m^3/s. The River Girvan flows through Straiton, Crosshill and Dailly before entering the sea at Girvan. Upstream of Kirkmichael area, the river is fast flowing with many rocky and turbulent sections. Land uses within the catchment include commercial forestry and rough grazing.

The River Stinchar is 46 km in length and has a catchment area of 314 km^2. The Stinchar contains one SSSI situated near the mouth of the Stinchar on the gravel banks designated for ground nesting birds. There is relatively little intensive agriculture and the overall water quality is excellent. There are four main tributaries: Muck water, Duisk, Water of Assel and Water of Tig. The Stinchar runs through Barr, Pinwherry, Colmonell and Ballantrae**.**

Species Present in ART area

The river catchments were surveyed for the presence and abundance of giant hogweed (GH), Himalayan balsam (HB) and Japanese knotweed (JK). The initial surveys were completed for the River Ayr, River Irvine and Water of Girvan during 2008; and the River Garnock, River Doon and River Stinchar during 2009. A total of 739 km of waterways (including both banks) was surveyed. Of this, 188 km (25 %) was infested with GH, and 257 km (35 %) and 204 km (28 %) were infested by JK and HB, respectively. All lengths provided are the sum of both banks. The distribution of INNPS varied from absent, to present at > 70 % of the surveyed waterway, and intensity of infestations at infested sites varied from rare (1 – 10 %), to dominant (≥ 75%), between catchments and subcatchments. This is summarised in Table 1, and comprehensively described in Appendix I.

Initially, the primary focus was on GH due to its associated health risks to humans. The initial survey identified that GH was present along the majority of the River Ayr catchment (including Water of Coyle, Lugar Water and Water of Fail), often at relatively high levels of abundance. As such, this was the target of the first INNPS control efforts. Along the remaining 5 rivers there were high coverage levels of at least one INNPS. The distribution and abundance of INNPS are further described in Table 1 and Figures 2 – 4.

Table 1 A summary of the length of waterway infested by three INNPS across different river systems in the ART area. The length surveyed in each subcatchment is given in parentheses in the second column. For species, GH = giant hogweed; JK = Japanese knotweed; and HB = Himalayan balsam. The lengths and percentages give the amount of each subcatchment infested by each species. The lengths infested by each species were measured independently. A more detailed summary including DAFOR scores is provided in Appendix I.

Catchment	Sub-Catchment (length)	Species	Length and % infested
Garnock	Main stem (67 km)	GH	8.1 km (12 %)
		JK	28.8 km (43 %)
		HB	43.3 km (65 %)
	Lugton Burn (8.1 km)	JK	2.8 km (35 %)
		HB	< 1km
Irvine	Main stem (118.6 km)	GH	41.1 km (35 %)
		JK	57 km (48 %)
		HB	57 km (48 %)
	Annick Water (44.9 km)	GH	35.5 km (79 %)
		JK	10.9 km (24 %)
		HB	10.1 km (23 %)
	Kilmarnock Water (8 km)	GH	0.6 km (8 %)
		JK	5.8 km (72 %)
		HB	4.8 km (60 %)
	Cessnock Water (15.5 km)	JK	2.1 km (14 %)
		HB	8.8 (57 %)
Ayr	Main stem (107.5 km)	GH	79.6 km (74 %)
		JK	27.8 km (26 %)
	Water of Coyle (28.5 km)	GH	18.3 km (64 %)
		JK	0.3 km(1 %)
	Lugar Water (30.6 km)	GH	1.1 km (4 %)
		JK	15.5 km (51 %)
Doon	Main stem (83.8 km)	GH	1.5 km (2 %)
		JK	12.2 km (15 %)
		HB	2 km (2 %)
	Chapelton Burn (4.4 km)	HB	3.1 km (70 %)
	Purclewan Burn (3.9 km)	HB	0.84 km (21 %)
Girvan	Main stem (88 km)	JK	27.2 km (31 %)
		HB	4.6 km (5 %)
	Dyrock Burn (14.7 km)	JK	3 km (20 %)
Stinchar	Main stem (61.8 km)	JK	42.4 km (69 %)
		HB	49.7 km (81 %)
	Duisk Water (20.8 km)	JK	14.9 km (72 %)
		HB	17.2 km (83 %)
	Muck Water (6.3 km)	JK	5.3 km (83 %)
		HB	0.3 km (4 %)
	Water of Tig (5.9 km)	JK	0.16 km (3 %)
		HB	1.7 km (29 %)

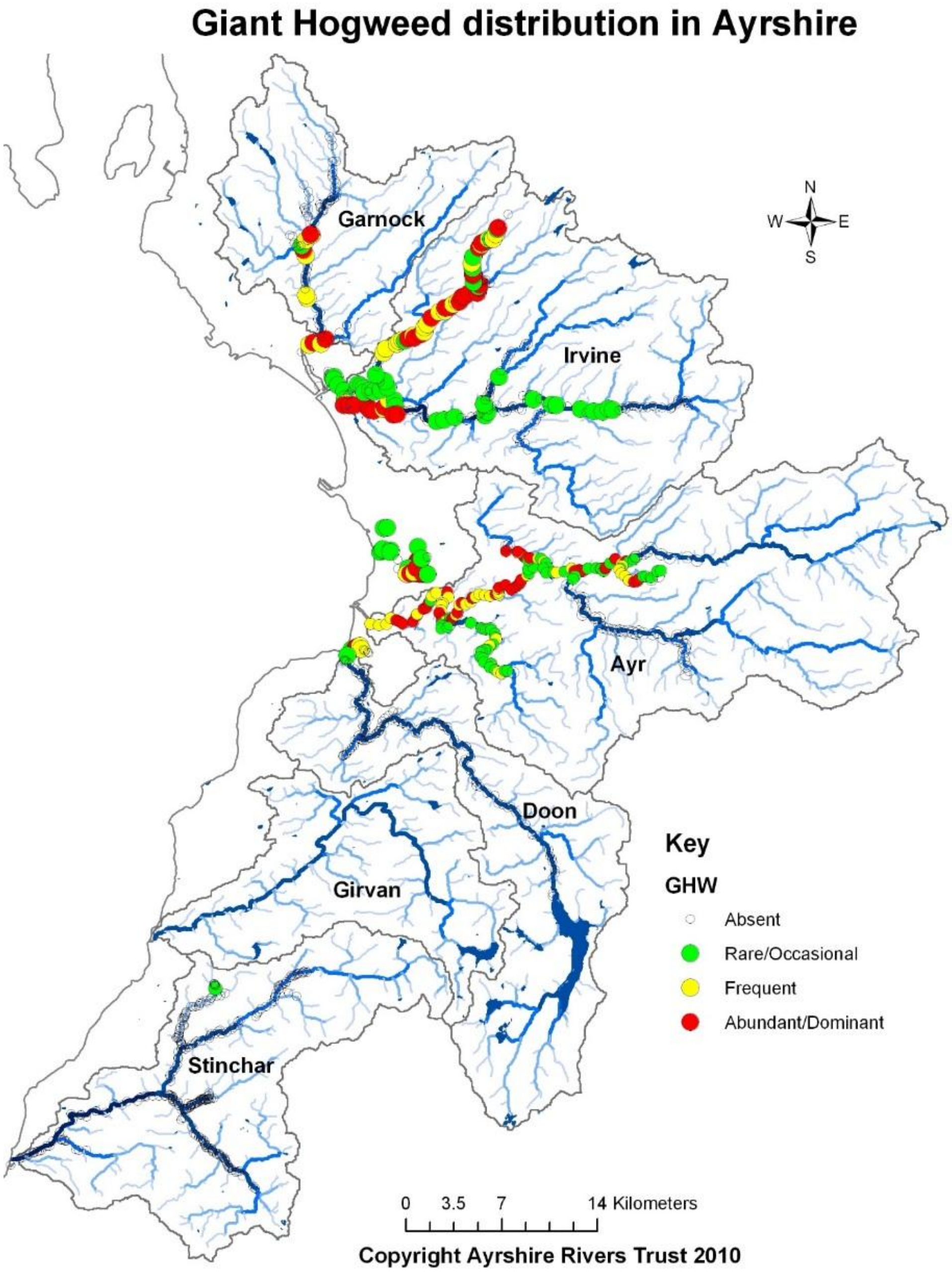

Figure 2 Map showing the distribution and abundance of Giant Hogweed in the ART area, as recorded during pre-treatment surveys in 2008 and 2009. Different colours represent different intensities of infestation as indicated in the key on the right hand side of the map.

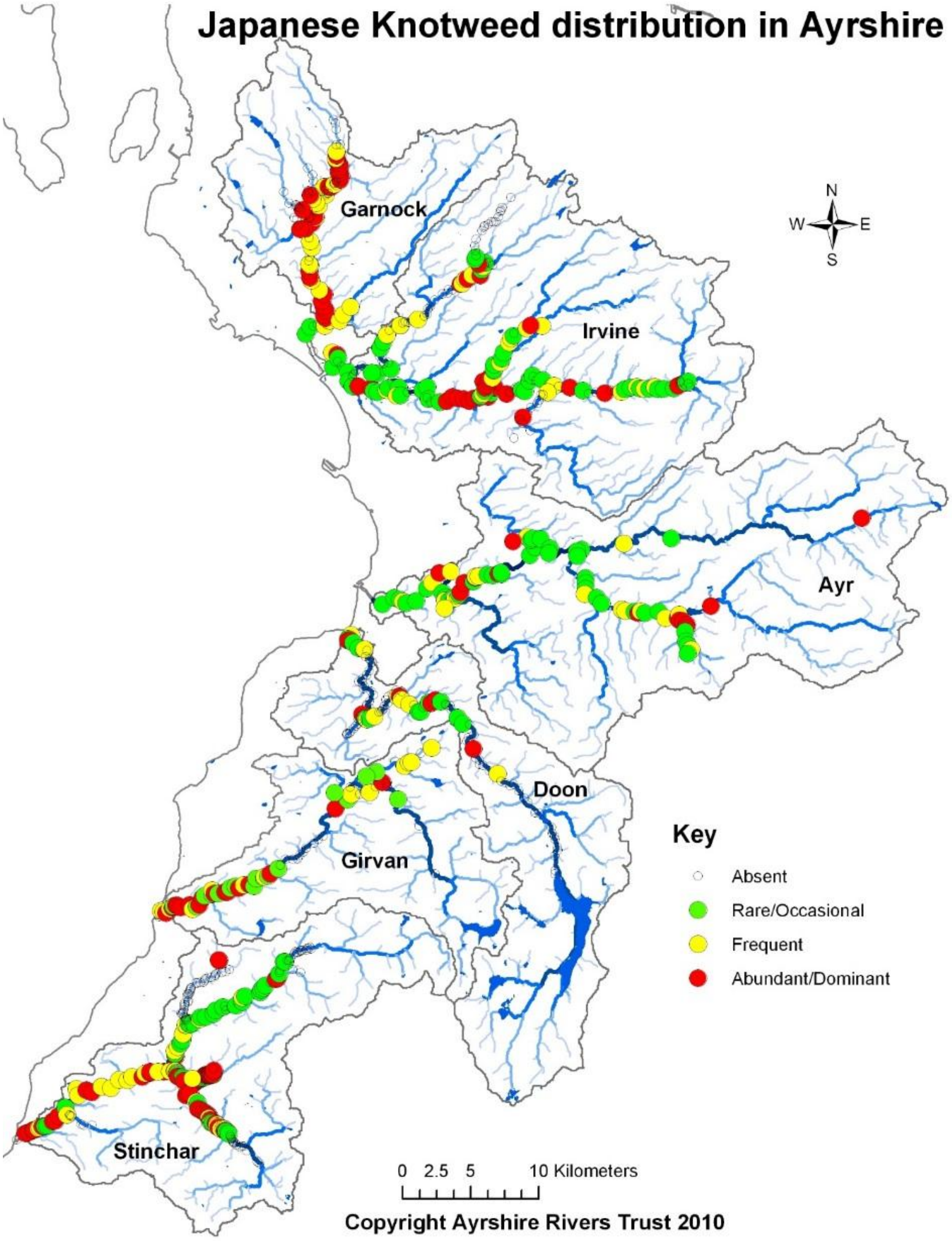

Figure 3 Map showing the distribution and abundance of Japanese Knotweed in the ART area, as recorded during pre-treatment surveys in 2008 and 2009. Different colours represent different intensities of infestation as indicated in the key on the right hand side of the map.

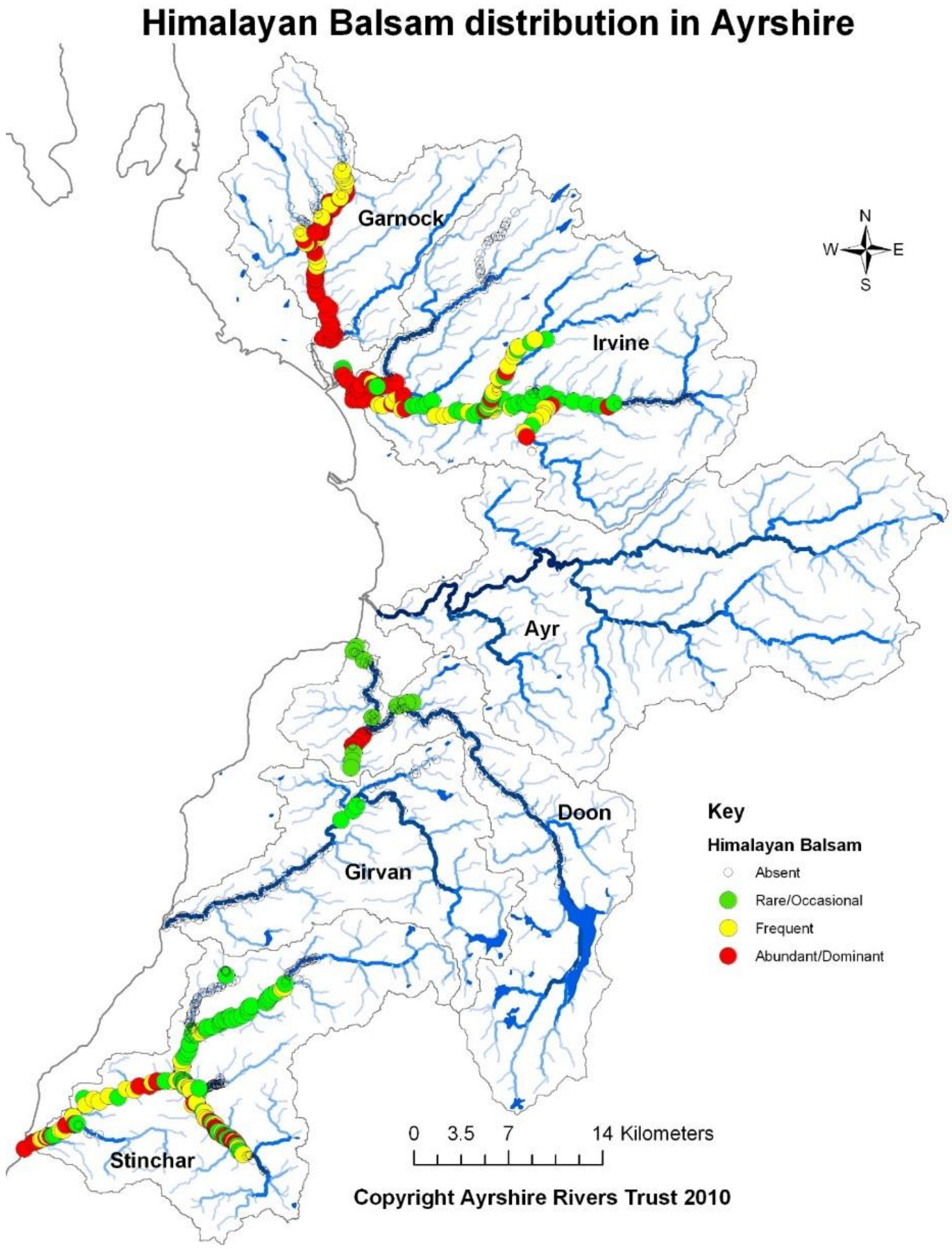

Figure 4 Map showing the distribution and abundance of Himalayan balsam in the ART area, as recorded during pre-treatment surveys in 2008 and 2009. Different colours represent different intensities of infestation as indicated in the key on the right hand side of the map.

How ART obtained data

ART staff surveyed all of the main stem rivers and sub-catchments mentioned above using INNPS survey sheets and DAFOR scale (Dominant > 75 %; Abundant = 51 – 75 %; Frequent = 26 – 50%; Occasional = 11 – 25 %; Rare = 1 – 10 %) to assess and categorise relative abundances. Original surveys were recorded manually and measured as percentage total coverage along each survey stretch. Survey stretches varied in length and way points were chosen using permanent landmarks. All surveys were extended for 1km beyond the last recorded plant presence to make sure that all present species were recorded.

The 3 maps below (Figs. 2 – 4) were produced from this data. Since the initial surveys, further resurveys have been undertaken to quantify any changes in coverage and abundances, and thus monitor how successful control has been. These surveys were carried out in 2012 and 2013 in all but the Stinchar catchment which has still to be completed. Most of these were done manually as before but a PDA was also used in some instances to record data.

All surveys were extended for 1km beyond the last recorded plant presence to make sure that all present species were recorded. The source of the GH on the River Ayr was located and an initial problem with obtaining the landowner's permission for access to control was eventually resolved.

3. Treatment:

For the CIRB (Controlling priority invasive non-native riparian plants and restoring native biodiversity) project, ART issued tenders so the majority of control work would be delivered through contractors. The remaining control would be carried out by the project officer and a group of trained volunteers. A strategic control programme was developed determining that control work started at the source of the plant population and then progressed successively downstream to the sea. With this approach, the control of infested sites is less likely to be compromised by infestation from upstream (as any upstream sites will have already been treated) and any accidental expansion is in the direction of ongoing control (downstream), and will be treated subsequently. This would be the approach taken for both JK and HB control. For GH control ART adopted a 'no plant goes to seed' approach but it was evident that plants in the lower catchment grow quicker than those further upstream. With this in mind, control of GH would start at the sea and work upstream to the source of the plant population. Had contractors been unable to reach this source the project officer and volunteers would step in to make sure nothing was missed however this situation did not arise.

Each tender described the work ART expected of the successful contractor and which methods of control were acceptable for which species. For example, we only accepted spraying for Giant Hogweed; either spraying, or stem injection, for Japanese Knotweed; and strimming, hand pulling, or spraying for Himalayan Balsam. The area covered by the tenders increased with each successive year. Once all of the Giant Hogweed had at least one year of control, Japanese Knotweed tenders were then introduced, and in 2013 two Himalayan Balsam tenders were also produced. For all sites out with the areas tendered to contractors, staff and fully trained volunteers carried out the control work.

Each INNPS is different in terms of biological growth, appropriate control treatments, and the optimal time of year for treatment efficiency. Giant Hogweed can grow very fast, especially in areas with direct sunlight. Himalayan Balsam can be controlled by various methods: it can be hand pulled and left over a tree or fence to dry out and decompose; it can be strimmed before seed development; or it can be sprayed. Generally, spraying was only used for large areas of HB coverage, but balsam grows in a wide variety of locations and conditions, many of which are tricky to access, and single plants are also not uncommon. Thus, hand pulling is often the most practical method. Controlling HB takes place during July and August and is weather-dependent. Balsam growth and seed development is quicker in dry summers, and in such conditions early September may be too late for effective control treatment. Japanese knotweed is controlled by spraying or stem-injection when it is in flower, later in the year than the other INNPS (August – October). However, the control must take place before the first frost (as recommended on page 2 of the manufacturers label for Roundup Pro-Biactive 450), this can result in poor control results. As an experiment, ART carried out control on a stand of JK the day after the first frost in winter 2012, results were very poor with the stand growing back fully in 2013. All of the areas infected with different INNPS were only fully treated once per year, although the contractors re-walk the rivers to spray/control any missed plants, to enhance the impact, ART found this method to be effective in the first year of control so continued to adopt this throughout the term of the project.

The control treatment work carried out by contractors was inspected by the trust staff and if any area was found to have been missed then the contractors were asked to redo the work. The project officer also kept a record of before and after photographs for the purpose of documenting any re-growth of both INNPS and native vegetation (Fig. 5).

Site Name: River Irvine catchment – Japanese Knotweed	
Grid Ref: NS 356 385	
 Before (Aug 2013)	 After (May 2014)

Site Name: River Ayr Catchment - GH	
Grid Ref: NS 383 224	
 Before (May 2012)	 After (May 2013)

Figure 5 Before and after photographs illustrating the effect of *include treatment type* on Japanese knotweed (upper panels) and giant hogweed (lower panels).

Prevention measures were also introduced through awareness raising events and in each tender contractors were asked to produce a biosecurity plan. Awareness raising events were held for all three local councils with many employees in attendance. ART discussed plant identification, the importance of biosecurity, control methods, equipment and health and safety. Other events also took place with presentations given to angling clubs, landowners and local community groups.

4. Outputs, Outcomes and Impacts:

a) Outputs:

Contractors

Table 2 shows the areas covered by contractors from 2011 to 2014, the number of man days spent, the costs involved and the amount of chemical used. In general it is clear with GH control that the number of man days, cost and chemical used show a decrease year on year with the exception of cost from 2011-2012. This rise in cost is attributed to the competitive tender process, it is difficult predict the costs for the future when working with a fair and competitive tender process like the one adopted throughout the CIRB project. In 2014, GH control was down to 114 man days but for the future ART cannot see this reducing by much more, although densities are decreasing each are still has to be walked and inspected which takes time. The figures for JK control show a similar trend although there was a jump in costs in 2014 as new areas were added to the control strategy. Due to the sheer scale of the infestations and the size of the ART area, together with the discovery of new sites and the ongoing training of volunteers, costs did not decrease year on year through the project Table 3). However, this is not in any way considered to be indicative of the longer term scenario, as once infestation intensities start to come down (after one or two years treatment for most species) costs should approach a baseline, correlating with the time taken to adequately resurvey the area and the much reduced treatment costs of controlling regrowth. A detailed breakdown of control efforts, costs and rates by site and year are given in Appendix II.

Table 2 Summary of length of infested areas treated by year, treatment area and INNPS, along with a breakdown of associated expenditure, chemical use and number of man days used

Year	Species	Man Days	Cost	KM covered	Chemical Used (L)
2011	GH	138.5	£24,907.50	143	Not quantified
2012	GH	127.75	£27,513.75	143	111.73
2013	GH	118	£22,430	143	87.51
2014	GH	114	£21,792	143	87.1
2011	JK	74	£14,360	46.5	Not quantified
2012	JK	70	£14,365	73	93.55
2013	JK	66	£10,480	131.5	62.56
2014	JK	84	£17,440	161.5	118.02
2012	HB	10	£500	8	Manual control
2013	HB	3	£6250	16.5	15.2

Table 3 A summary of project expenditure between 2010 and 2014. * costs for 2014 are estimates.

CIRB project Costings (£)	(2010)	(2011)	(2012)	(2013)	(2014)*
Contractor charges	0	£40,236.50	£41,243.50	£41,430.34	£40,194
Equipment (includes chemical)	0	£4,724.68	£ 10,575.41	£10,417.03	£15,000
Staff time	£3367.15	£20,041.03	£22,748.49	£21,531.47	£25,600
Volunteer training	0	£3,636.31	£8,835.77	£11,022.10	£9,180
Other expenses (van hire and fuel)	£79.60	£680.67	£3720.86	£4,940.94	£4,610
Total:	£3,446.75	£71,319.19	£87,124.03	£89,341.88	£81,084

Volunteers

In total, ART have trained 57 volunteers in NPTC City & Guilds PA6 AW spray training with 53 of these passing the exam. The most reliable were given their own equipment and chemical and working groups were formed, these would be led by the project officer but with some smaller groups working alone and reporting back to the project officer who would monitor control. 4 volunteers were also trained in Lantra Strimmer and Brushcutter to be used in the control of Himalayan Balsam, these volunteers already had access to the equipment through local angling clubs. Around 40 of these volunteers are still active and as well as being used during the project they can continue with the control strategy after the project has come to an end. 6 of these volunteers would go on to gain employment with contractors working in the area, this local knowledge was to prove vital to contractors who had not worked in the area before.

The total number of volunteer days could not be quantified precisely but over the course of the project in excess of 300hrs volunteer time was recorded. Having passed the training course some volunteers were equipped with one Knapsack sprayer, two additional types of nozzles, one 5l container of Roundup Pro Biactive 450g/l, five pairs of gauntlets and five coveralls. Depending on use, the Knapsack components can break, but through the duration of the project we have only needed to replace four of the knapsacks distributed to volunteers. Not all of the volunteers received this equipment with some being kept in storage and distributed on volunteer days as required. All of the chemical purchased was retained in a chemical store and records were kept of quantities in storage and the quantity and type of products that were distributed to volunteers. Coveralls constantly need replaced as they are extremely thin and when working next to a bramble bush they easily tear and shred, therefore a good stock of these was always retained for replacements.

b) ***Outcomes and Impacts:***

The rivers falling under the project area were resurveyed for INNPS, post-treatment, during 2012 and 2013 (Figs.7 – 8). The River Stinchar and the upper River Irvine have still to be resurveyed but these will be completed in 2015. As such, data for these areas have not been included, but there is no reason to believe that the results in these sections will differ greatly from the areas that were resurveyed.

The post treatment surveys showed substantial impacts of control on all of the target INNPS. All species showed meaningful relative decreases in coverage for infested sites that were treated, as well as areas where clearance was considered to have been achieved. However, the level of success varied considerably between species, with the greatest results observed with giant hogweed and the most significant outstanding challenge presented by Himalayan balsam. For all INNPS the reductions were widespread across the ART area, as clearly illustrated in Figures 9 –11.

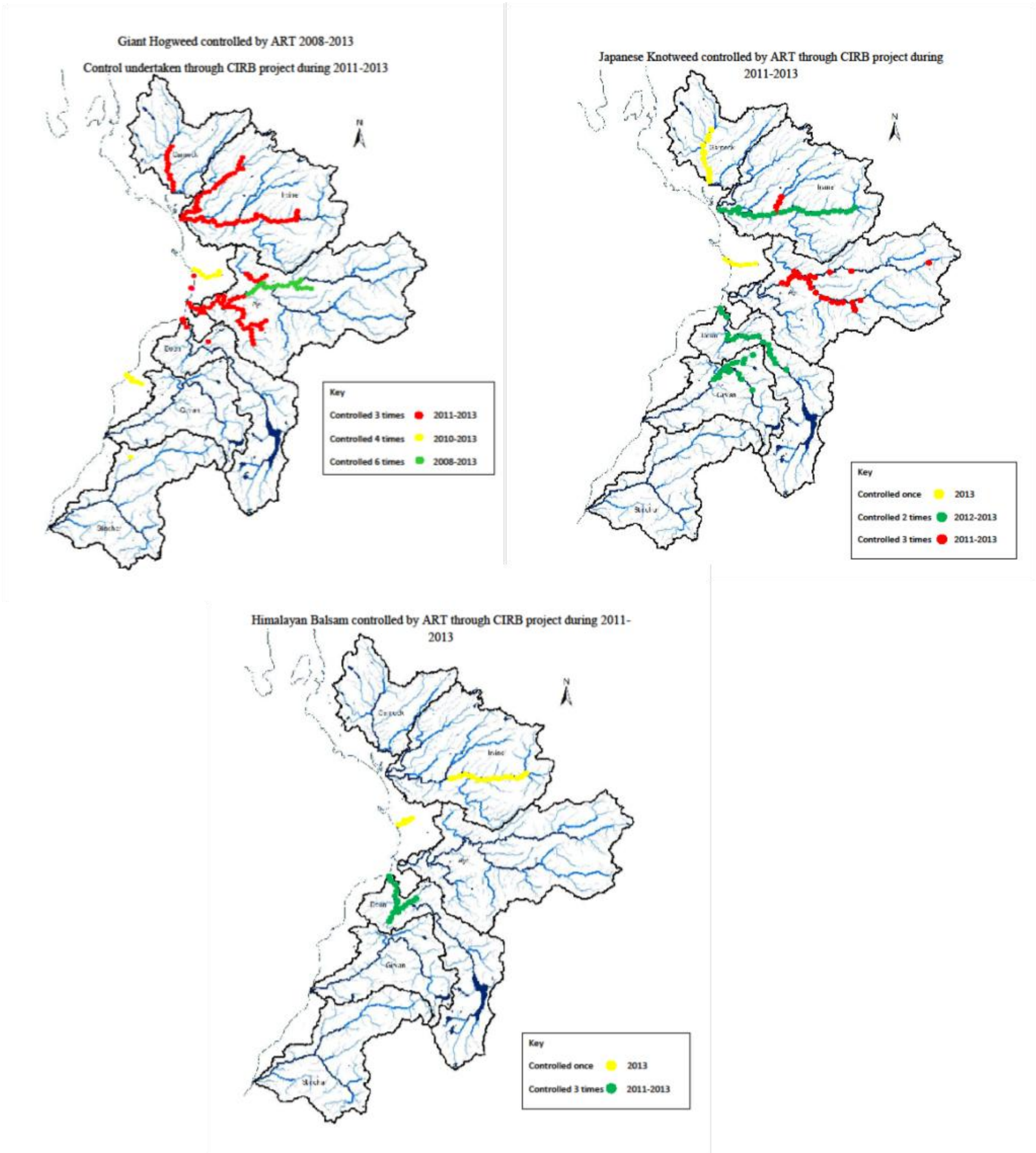

Figure 6 Map illustrating the distribution of INPPS control effort in the ART area between 2010 and 2013, for giant hogweed (top left), Japanese knotweed (top right), and Himalayan Balsam (bottom).

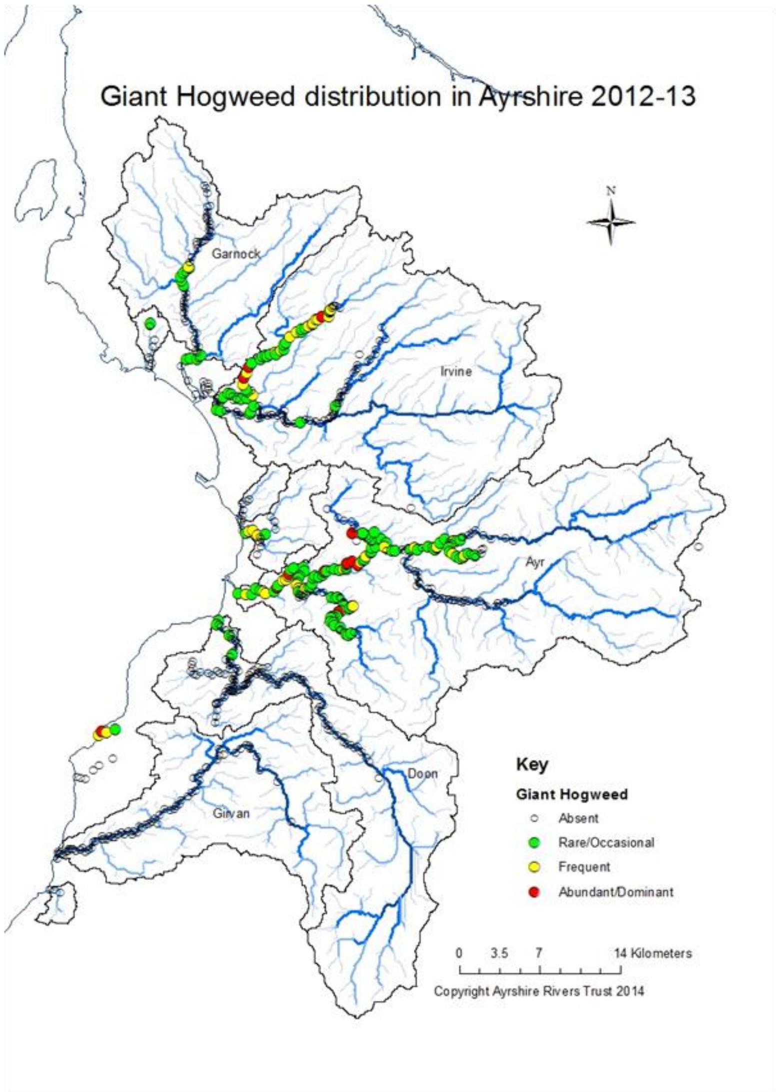

Figure 7 Map showing the distribution of giant hogweed in the ART area following the post-treatment survey in 2012-2013.

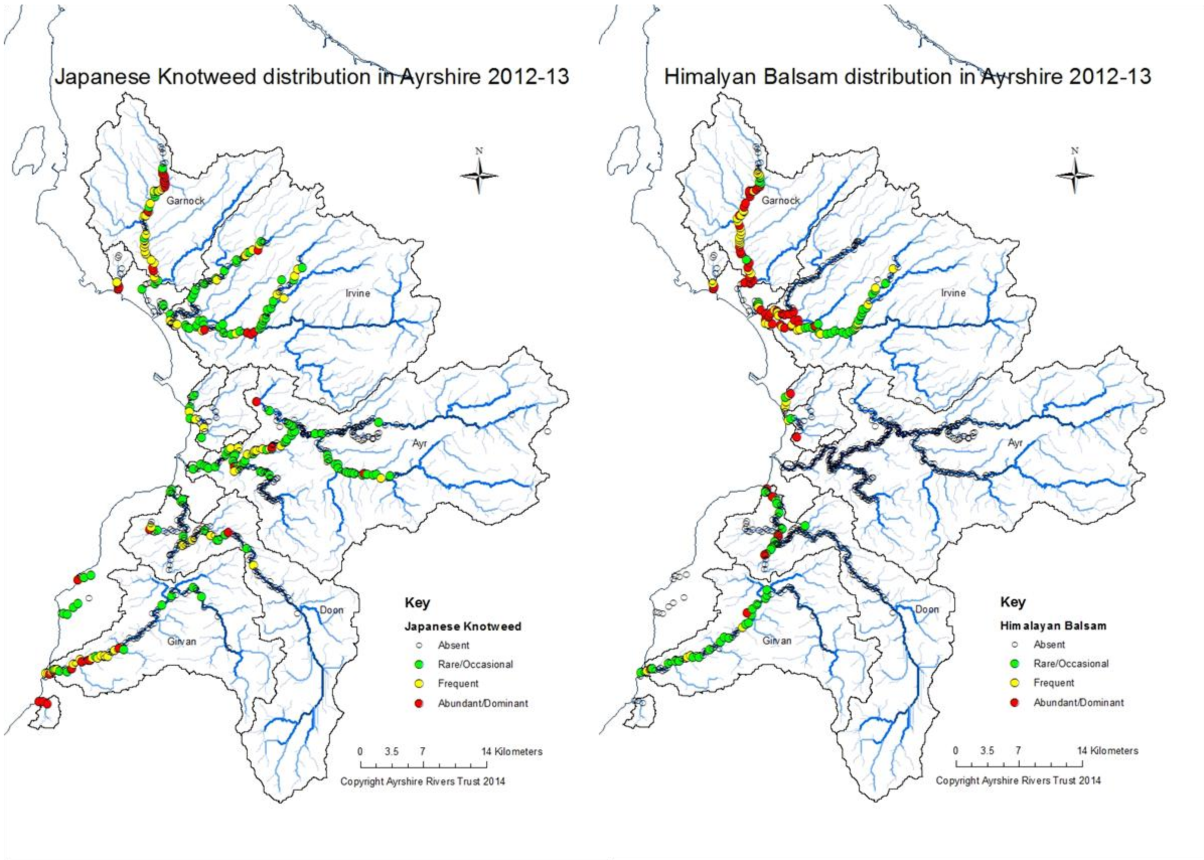

Figure 8 Maps showing the distribution of Japanese knotweed (left) and Himalayan balsam (right) in the post-treatment surveys in 2012 – 2013.

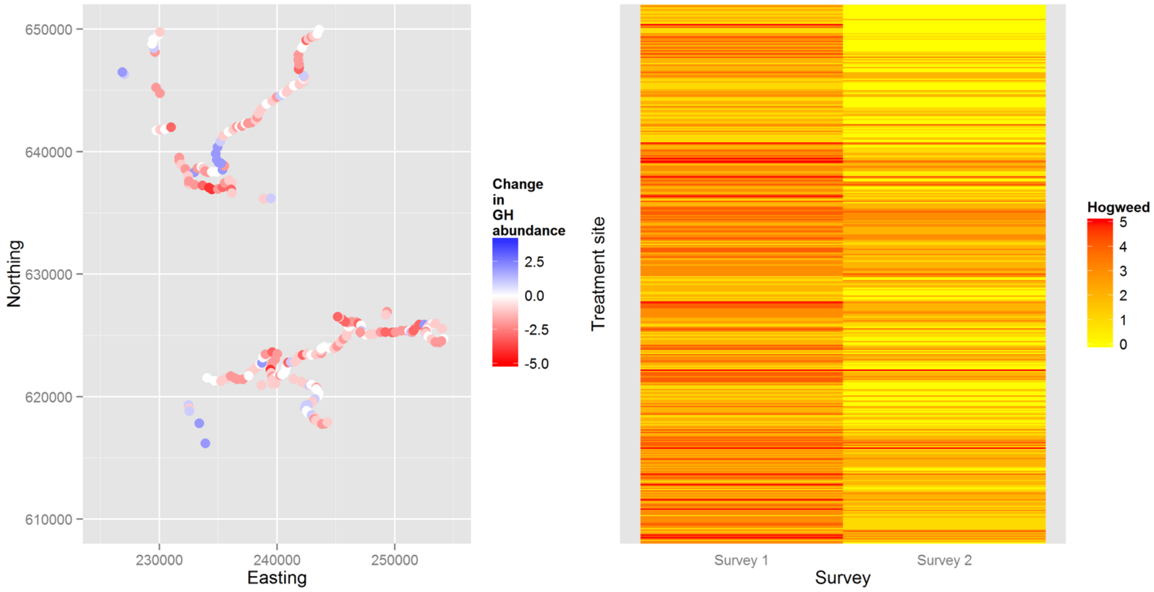

Figure 9 Two plots illustrating the change in abundance of giant hogweed (DAFOR scale) in the ART area between the first (pre-treatment) and second (post treatment) surveys. The plot on the left shows the difference between the first and second surveys. Each point represents a survey site and points in the red spectrum indicate a decrease in GH. E.g. a dark red point indicates a site that has changes from dominant (≥ 75 % coverage) to absent (0 % coverage). Note that the vast majority of sites show a decrease. The heat plot on the right shows the actual intensity of GH infestation at each of 415 sites in the first (left panel) and second (right panel) surveys. Each horizontal line is an individual site and different thicknesses of lines result from sites with the same infestation level being next to each other. Dark red lines indicate a high level of infestation and yellow lines indicate no infestation. Note that the right panel is substantially more yellow than the left panel and that many sites became clear of GH by the second survey. For clarity only sites where GH was detected in the first survey are included and background detail has not been included in the map on the left. Together these plots clearly illustrate the broad scale success of the control work in reducing GH abundance.

Across all treated sites, giant hogweed was reduced from an average of 2.6 to 1.4 on the DAFOR index, from approximately 40 % to 16 % coverage (estimated on a numerical DAFOR index bounded by 0 – 5 DAFOR points, corresponding to 0 – 100 % coverage). Of the 415 previously infested sites, 125 were considered to be free of GH in the post-treatment survey; a total cleared length of *c.* 53.45 km, approx. 31% of the previously infested area (Fig. 9). In contrast, GH was only present at 23 sites in the second survey from where it had been absent in the first survey, a total of 10.7 km.

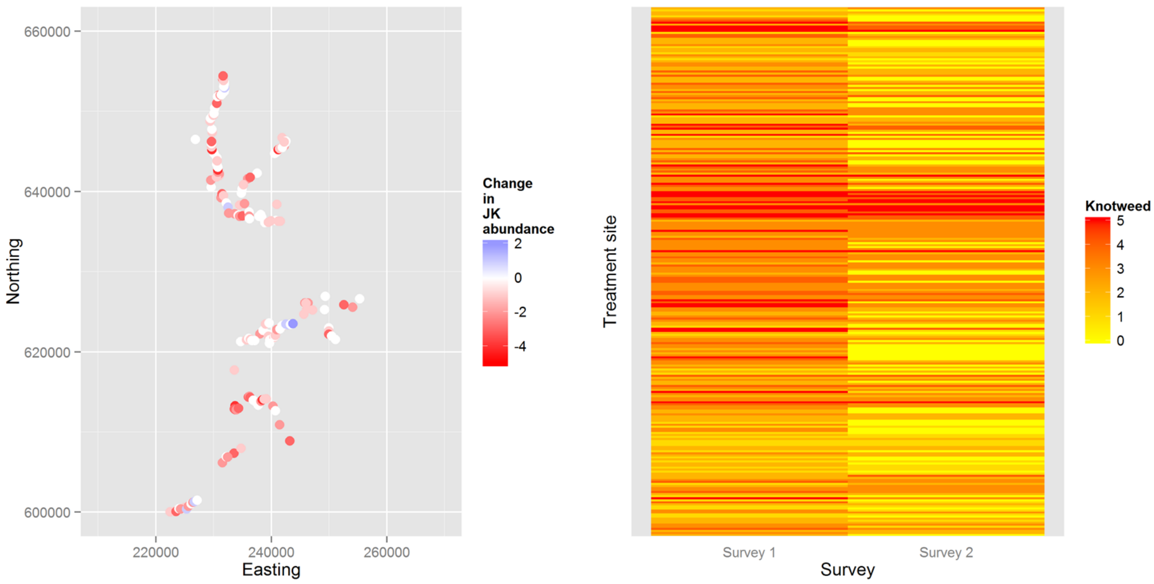

Figure 10 Two plots illustrating the change in abundance of Japanese knotweed (DAFOR scale) as a result of control in the ART area between the first (pre-treatment) and second (post treatment) surveys. The plot on the left shows the difference between the first and second surveys. Each point represents a survey site and points in the red spectrum indicate a decrease in JK. E.g. a dark red point indicates a site that has changed from dominant (≥ 75 % coverage) to absent (0 % coverage). Note that the majority of sites show a decrease. The heat plot on the right shows the actual intensity of JK infestation at each of 259 sites in survey 1 (left panel) and survey 2 (right panel). Each horizontal line is an individual site and different thicknesses of lines result from sites with the same infestation level being next to each other. Dark red lines indicate a high level of infestation and yellow lines indicate no infestation. Note that the right panel is substantially more yellow than the left panel and that many sites became clear of JK by the second survey following treatment. For clarity only sites where JK was detected in the first survey are included and background detail has not been included in the map on the left. Together these plots clearly illustrate the broad scale success of the control work in reducing JK abundance at infested sites.

An average reduction from DAFOR 2.8 to 1.9 was observed for sites infested with Japanese knotweed between the first and second surveys; an average change from approximately 45 % to 24 % coverage. Seventy six of 259 previously infested sites were recorded as free from JK post-treatment, a total of ≥ 29.7 km (the length of some sites was not recorded), corresponding to approx. 24 % of the previously infested area (121.7 km). However, 59 sites that were previously not infested recorded JK in the second survey, a total of 25.9 km.

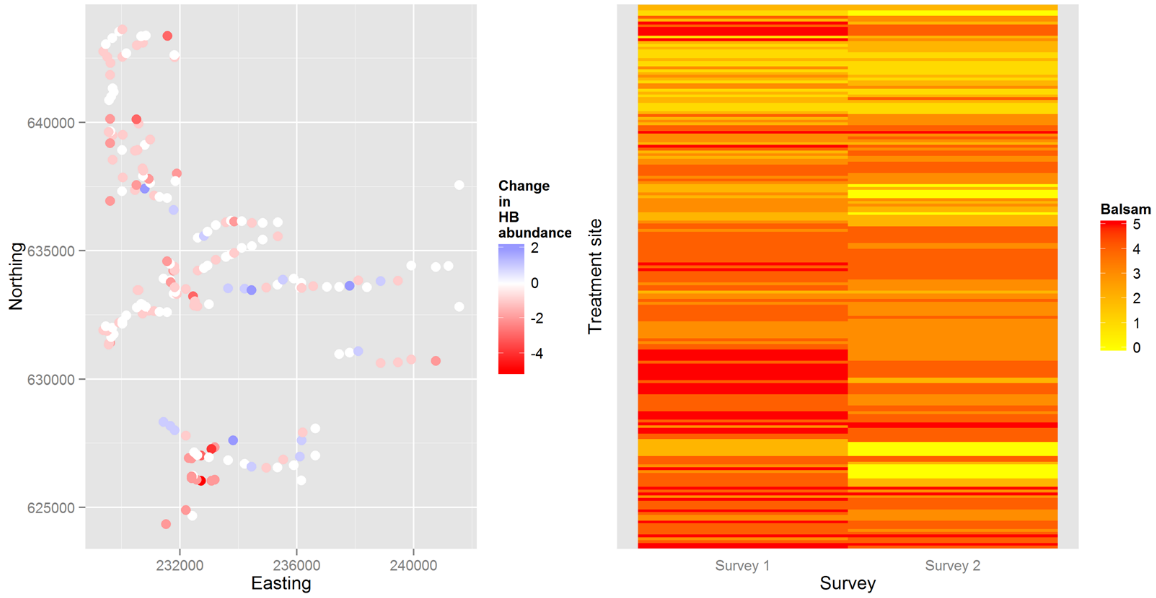

Figure 11 Two plots illustrating the change in abundance of Himalayan balsam (DAFOR scale) in the ART area between the first (pre-treatment) and second (post treatment) surveys for treated sites. The plot on the left shows the difference between the first and second surveys. Each point represents a survey site and points in the red spectrum indicate a decrease in HB. E.g. a dark red point indicates a site that has changes from dominant or abundant (≥ 51 % coverage) to absent or rare (≤ 11 % coverage). Note that the many sites show a decrease and very few show an increase. The heat plot on the right shows the actual intensity of HB infestation at each of 226 sites in survey 1 (left panel) and survey 2 (right panel). Each horizontal line is an individual site and different thicknesses of lines result from sites with the same infestation level being next to each other. Dark red lines indicate a high level of infestation and yellow lines indicate no infestation. Note that in the right panel (survey 2) there is a general tendency for fewer dark red sites and more yellow sites in comparison to survey 1. For clarity only sites where HB was detected in the first survey are included and background detail has not been included in the map on the left. Together these plots illustrate that the control work has been broadly successful at reducing HB abundance.

Generally speaking, the intensity of pre and post-treatment coverage at sites infested with Himalayan balsam were more severe. Across all infested sites the average DAFOR index was nevertheless reduced from 3.4 to 2.8, an average change from 60 % to 45 % coverage following treatment. Seventeen sites were cleared completely of HB, a total of ≥ 6.7 km (the length of some sites was not recorded), corresponding to approximately 8 % of the previously infested area. However, by the second survey HB had colonised 58 sites that were not infested in the first survey, a total of 25.7 km.

The majority of the control work was delivered by contractors, whilst a number of smaller infested areas were treated by volunteers. For all INNPS the work completed during the three control years of the CIRB project have resulted in a much lower densities in treated areas in comparison with the original surveys. New areas containing the INNPS have been identified and many of these have been surveyed for control to commence in 2014.

In areas that contained high density of JK and HB it was noted that in the following year the HB had spread onto the area where the JK once was, as this ground has now been opened up to the sunlight. During 2012 a Catalonian intern spent a few months with the Trust and researched Giant Hogweed and its roots. During her time she had various transects and counted the number of plants touching it along a 100m stretch this was done both before and after treatment. With the small amount of research completed it did show a higher abundance of native plants after the treatment, but this would need repeated throughout the years and unfortunately she was only with ART for 3 months but further botanical surveys were to be carried out by QUB in 2014, the results of which are unknown at present.

5. Conclusions:

The control work completed by ART thus far is proving to be successful in terms of effectively reducing INNPS abundances in treated areas. This has been particularly the case for giant hogweed where not only have abundances been substantially reduced, but where the rate of clearance outstrips the rate of colonisation by about five to one. Giant hogweed remained present at ≥ 127 km of riverbank in the second survey (2012 – 2013). The net clearance was approximately 42 km (53 km cleared – 11 km colonised) which would suggest that complete eradication is achievable, though it will require a sustained effort. It is important to bear in mind that clearance rates can be expected to improve as the number and intensity of sources of colonisation are diminished. Similarly ≥ 108 km of waterways remained infested by JK. However, the colonization potential of JK was much higher and the net clearance was more modest at about 4 km (29.7 km cleared – 25.9 km colonised). Notwithstanding, the control work began to reverse the spread of JK as well as heavily impacting the abundances, and therefore both recolonisation and eradication potential, of infested sites. This demonstration that large areas can be cleared completely suggests that a downstream clearance strategy should ultimately be successful.

The effectiveness of Himalayan balsam control was less clear cut. The distribution of HB actually increased between the first and second survey due to the length of newly colonised waterways outweighing those that were cleared. However, HB was the lower priority INNPS for the project and therefore received a fraction of the effort employed on GH and JK, a total of only 57 days. As such, the observed expansion most likely reflects the natural colonisation potential of the species in uncontrolled areas, as well as a potentially increased colonisation rate of sites from which GH and JK had been cleared. Additionally, the majority of HB work was undertaken in 2013. Thus, four or five years had passed between the first and second surveys, with relatively little control effort being deployed in that time, so it would have been unlikely for the overall distribution to have declined in such circumstances. The clearance success (considering only sites that were cleared and not accounting for sites where abundance was reduced) were actually comparable between HB (0.11 km per day) and GH (0.13 km per day). All else being equal, reallocating 160 days of control effort from GH (which received a total of 408 days) to HB would have reduced the area cleared of GH from approximately 54 km to 32 km, but should have been sufficient to halt the spread of HB. Approximately 93 km of surveyed waterways were found to be infested with HB in the second survey (though not all sites were measured for length, so the actual figure is more likely to be somewhere slightly in excess of the first survey figure of 108 km), which is comparable to GH and JK. Therefore, targeting a more equal share of resources towards HB in the future should bring eradication expectations in line with those for the other target species.

The mapping of INNPS presence and abundances in the waterways of Ayrshire is not yet fully complete, and control has thus far only been targeted on locations where presence has been ascertained. ART have primarily focused control on Giant Hogweed, whilst phasing in areas of Japanese Knotweed and finally Himalayan Balsam. From a technical perspective, all of the control methods that were used were found to work well and resulted in reduced densities at treatment sites (frequently to the point of clearance), especially for Giant Hogweed. Japanese Knotweed control has been successful with leaving treatment (whether spraying or stem injection) until late in the season when it is in flower. There were a few problems with treating JK when right next to the river, as when the river is in spate the stands are broken up, resulting in downstream spread. This is a very important factor in treating all three species, plant matter and seeds can spread freely downstream as water levels increase thus facilitating their spread. With Himalayan Balsam, contractors had been hired during 2012 and 2013 to control small areas. As this is a relatively new development we cannot fully comment on the results of this treatment, but previous hand pulling with volunteers and ART staff along burns has proven successful with very limited growth occurring the following year. In retrospect it may have made sense to focus a greater proportion of effort on HB an extra 160 days (in addition to the 57 allocated) should have been sufficient to clear an area that would have halted the expansion of the species, whilst also reducing the colonisation potential.

A problem with JK is that landowners and the general public do not know what it is, or how to control it. Many of them had been cutting and/or strimming it, especially if it was present along a public pathway, but were not aware that these processes only spread the plant. ART have tried to raise awareness about this plant by running seminars with the three local councils, and distributing leaflets and information sheets around the areas the plant is common. Unfortunately, we are unlikely to have reached everyone, and there are probably still people that will strim stands of JK present near their properties.

It is evident that awareness raising is a key factor when putting a control strategy in place, ART held a number of events and gave numerous presentations to local stakeholders including local councils, landowners, angling clubs and community groups. Project awareness signs were also erected in key areas along each catchment. These methods proved successful but there is also room for improvement, people must be encouraged to increase biosecurity practices in particular. Although there was previously no record of HB on the River Ayr catchment, three instances were recorded over the course of the project. One of these was a single plant discovered in an area frequented by anglers, some of these anglers also fish on other catchments in Ayrshire where HB is common, there is a high likelihood that seed was transported by one of these anglers. Another instance occurred on outlying burn where a trout fishery had brought in soil in 2012, by 2014 HB had spread from the fishery for about 2 miles of the burn. Luckily these instances were found and brought under control however they will require further control and monitoring in future years. While seed banks of GH and HB remain it is very important to get the biosecurity message out to the general public to try and reduce the risk of spread through human activity.

6. Lessons Learnt:

During the project we have learnt more about the effectiveness of control treatment work on the various INNPS species with respect to the timing of treatment, plant growth stage, and weather. The treatment methods employed were found to be effective and as such were continued through the duration of the project.

For GH, ART adopted a ‘no plant goes to seed’ and ‘spray every plant’ policy working from the bottom of the catchment up. Plants in the lower catchment were found to grow faster so starting at the bottom was the best option. By adopting this strategy it meant that no seeds would be added to the existing seed bank thus reducing the seed bank on a yearly basis.

For JK, ART largely adopted a ‘one spray’ method of control in late summer while the plant was in flower. Spraying at this time of year allowed for maximum amount of chemical to translocate to the root system as this is when the plant is transferring energy to the root system for winter. Stem injection techniques were also used and ART found this to be just as effective when carried out from the beginning August onwards. After control regrowth was still evident in some instances especially where ground had been disturbed. Further investigation is required to determine if in fact JK is actually being killed or whether or not it is just lying dormant. Root samples were taken in 2014 and passed to QUB for analysis.

ART found Himalayan Balsam difficult to control especially in areas where it was well established. Working from the highest point of infestation in the catchment downstream seemed to be the best option as we would be unable to bring full catchments under control over the period of the project. It became evident that eradication could be possible in a catchment with a low density of HB by repeatedly removing every plant on a yearly basis. Catchments with a high density covering many KM of riverbank would require a huge amount of time so at least by working from the top down each year we could reduce the risk of spread to areas already cleared.

The experience of ART is that using contractors leads to control work being completed within a short timescale, whereas solely relying on volunteers extends the time for treatment to be delivered and it cannot be guaranteed how many people will turn up on the arranged days. This could mean that areas are left untreated and with GH and HB this can result in further spread of seeds.

Particular weather conditions were found to be challenging. For example, 2012 was an extremely wet year, which was problematic for the foliar spraying treatment of GH and JK, as a minimum post-application drying time of 1 hour is required (manufacturers label for roundup probiactive 450) in order to allow the plant to absorb the herbicide. The available drying time was often very short due to frequent rainfall. ART and contractors were able to combat this by increasing man power when weather conditions allowed and this requirement was written in to the original tender documents. In contrast, the weather in 2013 was dry and warm, promoting rapid plant growth, but also enabling contractors to actively go out and control by any method without any weather restrictions.

Working with volunteers can itself be challenging but can be very effective. Over the course of the project ART put forward 57 volunteers for training with 53 of these passing the exam. Once trained volunteers seemed initially enthusiastic but as time progressed it became evident that this enthusiasm was decreasing among some which inevitably led to some losing contact altogether. Once those willing or indeed able to put the time in were identified they were equipped and groups led by the project officer and other volunteers proceeded with control. It is important to remember that some volunteers may still be enthusiastic but just unable to attend on organised days, these volunteers were also equipped and once further training in control methods was supplied the volunteers could work together in small groups or pairs to carry out control reporting to the project officer who would monitor effectiveness. Around 40 of the original 53 are still active and have produced over 300hrs of control, these volunteers will be used in the coming years to continue with the control strategy but it will be vital for someone to oversee this work be it a member of ART staff or the most proactive volunteers. As an example of how successful this can be, ART trained 5 volunteers in the town of Stewarton who came forward after awareness raising events held by the project officer. The volunteers were fully equipped and would go on to control JK on the Annick Water which runs through the town, led by the project officer they put in over 100 hours of control from 2012-2014 and treat huge areas of JK, this story was reported in the CIRB newsletter of October 2014.

What has become clear is that control must continue after the project especially with GH and HB. Even one year of missed control can add enough seeds to the existing seed bank to render all of the previous work a waste of time. It is clear that anyone setting out to control these INNPS must be prepared for it long term. Previous experience on the Tweed catchment would suggest that at least 10 years and probably longer would be a conservative estimate for the control of GH.

Appendix I: summary of the distribution and abundance of three INNPS in the ART area. Area surveyed in each subcatchment is given in parentheses. Values of abundance are on the DAFOR scale (Dominant ≥ 76 %, Abundant 51 – 75 %, Frequent 26 – 50 %, Occasional 11 – 25 %, Rare 1 – 10 %. GH = Giant Hogweed; JK = Japanese Knotweed; HB = Himalayan Balsam. The lengths and percentages give the amount of each subcatchment that fall into that DAFOR category.

Catchment	Sub-Catchment	Species	Description of locations/abundance – DAFOR scale
Garnock	Main stem (67 km)	GH	Abundant/Frequent in certain areas, though not widespread through the catchment, high presence in tidal zone. Abundant = 0.54 km (1 %) Frequent = 1.67 km (2 %) Occasional = 5.13 km (8 %) Rare = 0.76 km (1 %) Absent = 58.90 km (88 %)
		JK	Present throughout the main stem in dominant/abundant and frequent densities. Dominant = 4.47 km (7 %) Abundant = 6.53 km (10 %) Frequent = 15.49 km (23 %) Occasional = 2.31 km (3 %) Absent = 38.22 km (57 %)
		HB	Present throughout the main stem in mainly the dominant/abundant category. A large problem for the catchment. Dominant = 12.20 km (18 %) Abundant = 20.84 km (31 %) Frequent = 7.38 km (11 %) Occasional = 2.78 km (4 %) Absent = 23.81 km (36%)
	Lugton Burn (8.06 km)	JK	Present in the lower section of the Lugton. Frequent = 2.75 km (34 %) Absent = 5.31 km (67 %)
		HB	Present at the confluence with the Garnock.
Irvine	Main stem (118.64 km)	GH	Present in rare/occasional densities, not widespread. Dominant = 1.29 km (1 %) Abundant =6.31 km (5 %) Frequent = 8.61 km (7 %) Occasional = 11.93 km (10 %) Rare = 12.97 km (11 %) Absent = 77.82 km (66 %)
		JK	Mainly present in rare/occasional densities, but widespread throughout. Dominant = 2.91 km (2 %) Abundant = 10.45 km (9 %) Frequent = 13.38 km (11 %) Occasional = 20.75 km (18 %) Rare = 9.46 km (8 %) Absent = 61.70 km (52 %)
		HB	Mainly present in dominant/abundant densities especially in the lower catchment, widespread throughout. Dominant = 3.97 km (3 %)

			Abundant = 6.02 km (5 %) Frequent = 12.24 km (10 %) Occasional = 19.55 km (16 %) Rare = 15.16 km (13 %) Absent = 61.48 km (52 %)
	Annick Water (44.88 km)	GH	Mainly present in dominant/abundant densities, widespread throughout. Abundant = 8.16 km (18 %) Frequent = 13.57 km (30 %) Occasional = 9.22 km (21 %) Rare = 4.59 km (10 %) Absent = 9.34 km (21 %)
		JK	Present in rare/occasional densities, not widespread. Dominant = 0.78 km (2 %) Abundant = 1.13 km (3 %) Frequent = 2.81 km (6 %) Occasional = 5.67 km (13 %) Rare = 0.48 km (1 %) Absent = 34.02 km (75 %)
		HB	Very low density, only present in the lower section close to the confluence with the River Irvine. Dominant = 3.77 km (8 %) Abundant = 5.17 km (12 %) Frequent = 1.20 km (3 %) Absent = 34.74 km (77 %)
	Kilmarnock Water (8.03 km)	GH	Extremely low density, but a few plants present. Rare = 0.55 km (7 %) Absent = 7.48 km (93 %)
		JK	A mixture of densities throughout this sub-catchment. Dominant = 0.96 km (12 %) Frequent = 1.52 km 19 %) Occasional = 2.42 km (30 %) Rare = 0.75 km (9 %) Absent = 2.39 km (30 %)
		HB	Rare/occasional and frequent densities present along the Kilmarnock Water. Dominant = 0.36 km (5 %) Abundant = 0.33 km (4 %) Frequent = 0.89 km (11 %) Occasional = 2.23 km (28 %) Rare = 1.01 km (13 %) Absent = 3.22 km (40 %)
	Cessnock Water (15.52 km)	JK	Very low density present at a few sites along the Cessnock. Abundant = 0.59 km (4 %) Frequent = 1.48 km (9 %) Absent = 13.45 km (87 %)
		HB	Widespread throughout this water, mainly in frequent and dominant/abundant categories. Abundant = 1.39 km (9 %) Frequent = 3.84 km (25 %) Occasional = 3.57 km (23 %) Absent = 6.72 km (42 %)
Ayr	Main stem	GH	Dominant = 4.30 km (4 %) Abundant = 18.85 km (18 %) Frequent = 23.07 km (21 %) Occasional = 21.24 km (20 %)

			Rare = 12.11 km (11 %) Absent = 27.92 km (26 %)
		JK	Low densities dotted along the length of the river. Dominant = 1.37 km (1 %) Abundant = 2.14 km (2 %) Frequent = 6.85 km (6 %) Occasional = 11.02 km (10 %) Rare = 6.37 km (6 %) Absent = 79.75k m (74 %)
	Water of Coyle (28.54 km)	GH	Low densities, widespread through this sub-catchment. Frequent = 2.50 km (9 %) Occasional = 6.60 km (23 %) Rare = 9.16 km (32 %) Absent = 10.29 km (36 %)
		JK	One stand of JK present near confluence with River Ayr. Frequent = 0.27 km (1 %) Absent = 28.27 km (99 %)
	Lugar Water (30.63 km)	GH	Low densities present near confluence with River Ayr. Occasional = 0.40 km (2 %) Rare = 0.73 km (2 %) Absent = 29.46 km (96 %)
		JK	Low densities, widespread through this sub-catchment. Dominant = 1.44 km (5 %) Abundant = 0.27 km (1 %) Frequent = 3.74 km (12 %) Occasional = 3.82 km (12 %) Rare = 6.21 km (20 %) Absent = 15.15 km (49 %)
Doon	Main stem (83.84 km)	GH	Low densities only present at tidal area of river. Occasional = 1.13 km (1 %) Rare = 0.32 km (<1%) Absent = 81.92 km (98 %)
		JK	Varied densities along the river, most were in the lower densities with a few stands in the dominant/abundant categories. Dominant = 1.25 km (15 %) Abundant = 1.47 km (18 %) Frequent = 4.29 km (5 %) Occasional = 4.48 km (5 %) Rare = 0.74 km (1 %) Absent = 71.60 km (85 %)
		HB	Small rare/occasional patches along the lower stretch of the river. Occasional = 0.37 km (<1%) Rare = 1.65 km (2 %) Absent = 81.82 km (98 %)
	Chapelton Burn (4.45 km)	HB	Dominant/abundant for the majority of the burn in the upper stretches with reduces to rare/occasional. Dominant = 0.39 km (9 %) Abundant = 2.02 km (46 %) Frequent = 0.69 km (15 %) Absent = 1.34 km (30 %)
	Purclewan Burn (3.93 km)	HB	Rare/occasional densities along a small stretch of the burn. Rare = 0.84 m (21%) Absent = 3.10 m (79 %)
Girvan	Main stem	JK	A mixture of densities throughout this river.

	(88.03 km)		Dominant = 2.10 km (2 %) Abundant = 7.80 km (9 %) Frequent = 6.01 km (7 %) Occasional = 10.65 km (12 %) Rare = 0.61 km (< 1 %) Absent = 59.97km (68 %)
		HB	Low densities present close to Doon catchment. We think this presence was from cross contamination. Occasional = 4.55 km (6 %) Absent = 82.60 km (94 %)
	Dyrock Burn (14.65 km)	JK	Frequent densities throughout the Dyrock. Frequent = 1.73 km (12 %) Occasional = 1.30 km (9 %) Absent = 11.63 km (79 %)
Stinchar	Main stem	JK	Dominant/abundant stands present along full stretch of river. Dominant = 0.8 km Abundant = 9.6 km Frequent = 15.9 km Occasional = 9.0 km Rare = 7.1 km Absent = 17.6 km
		HB	Dominant/abundant stands present along full stretch of river. Dominant = 0.7 km Abundant = 5.6 km Frequent = 15.4 km Occasional = 15.0 km Rare = 13.3 km Absent = 10.5 km
	Duisk Water	JK	Dominant/abundant stands present along full stretch of water. Dominant = 2.8 km Abundant = 2.0 km Frequent = 6.4 km Occasional = 2.6 km Rare = 1.3 km Absent = 5.7 km
		HB	Dominant/abundant stands present along full stretch of water. Dominant = 0.2 km Abundant = 3.3 km Frequent = 5.2 km Occasional = 6.6 km Rare = 2.0 km Absent = 3.4 km
	Muck Water	JK	Dominant/abundant stands present along full stretch of water. Dominant = 1.6 km Abundant = 1.1 km Frequent = 1.3 km Occasional = 1.1 km Rare = 0.2 km Absent = 1.1 km
		HB	Very low density at the confluence with the Stinchar. Dominant = 0 Abundant = 0 Frequent = 0 Occasional = 0.2 km Rare = 0.1 km Absent = 6.1 km

	Water of Tig	JK	One stand present of frequent density. Dominant = 0 Abundant = 0 Frequent = 0.2 km Occasional = 0 Rare = 0 Absent = 5.0 km
		HB	Dominant/abundant stands present near the confluence with the Stinchar. Dominant = 0 Abundant = 0.8 km Frequent = 0.6 km Occasional = 0.2 km Rare = 0.2 km Absent =3.5 km

Appendix II Breakdown of the project costs by treatment area, species and year, with information on the length of riverbank treated, the number of treatment days, the cost and the associated daily rate.

Project	Treatment Area	Species	Length of River - Single Bank length (both banks were treated)	No Days	Daily Rate	Total Cost
2010 - Doon DSFB	Doon Burns	HB	3km	12	50	£600.00
2011 - CIRB	Lower Irvine Catchment & Annick/Clerkland Burn	GHW	51km	42	198	£8,316.00
	Lower Ayr	GHW	18km	50	175	£8,750.00
	Upper Ayr, lower Lugar, Fail and Bogend Burn	GHW	30km	30	175	£5,250.00
	Garnock	GHW	24km	30	198	£5,940.00
	Coastal Burns	GHW	10km	10	380	£3,800.00
	Coyle	GHW	10km	8	198	£1,584.00
	JK Upper Girvan	JK	13.5km	27	175	£4,725.00
	Upper Ayr and Lugar	JK	21km	27	175	£4,725.00
	Kilmarnock water catchment	JK	12km	20	290	£5,800.00
2012 - CIRB	Garnock	GHW	24km	7.75	198	£1,534.50
	Lower Irvine Catchment	GHW	25km	19	198	£3,762.00
	Annick and Clerkland Burn	GHW	26km	22	198	£4,356.00
	Coyle	GHW	10km	7	198	£1,386.00
	Upper Ayr, lower Lugar, Fail and Bogend Burn	GHW	30km	26	220	£5,720.00
	Lower Ayr	GHW	18km	38	220	£8,360.00
	Coastal Burns	GHW	10km	8	220	£1,760.00
	Kilmarnock water catchment	JK	12km	12	220	£2,640.00
	Upper Irvine	JK	18km	12	220	£2,640.00
	Lower Irvine	JK	22km	35	175	£6,125.00
	Upper Ayr and Lugar	JK	21km	23	175	£4,025.00
	Doon Burns	HB	8km	10	50	£500.00
Doon DSFB	Doon	JK	30km	12	180	£2,160.00
2013 - CIRB	Garnock	GHW	24km	8	198	£1,584.00
	Lower Irvine Catchment	GHW	25km	18	198	£3,564.00
	Upper Ayr, lower Lugar, Fail and Bogend Burn	GHW	30km	23	180	£4,140.00
	Ayr lower	GHW	18km	32	185	£5,920.00
	Coyle	GHW	10km	9	198	£1,782.00
	Annick and Clerkland Burn	GHW	26km	20	198	£3,960.00
	Irvine	JK	40km	20	200	£4,000.00
	Ayr	JK	20km	10	200	£2,000.00
	Garnock	JK	24km	14	200	£2,800.00
	Upper Girvan	JK	13.5km	6	200	£1,200.00
	Pow Burn	JK	4km	6	200	£1,200.00
	Doon	JK	30km	10	180	£1,800.00
	Rumbling Burn	HB	2.5km	10	200	£2,000.00
	Upper Irvine	HB	9km	20	200	£4,000.00
	Doon catchment	HB	5km	5	50	£250.00