Green Recovery Challenge Fund

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NATURAL ENGLAND

TEES RIVERS TRUST

Project Details

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EVALUATION REPORT

Telling the story of Tees Rivers Trust's GRCF Project, its achievements and lessons learned.

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We would like to thank the National Lottery Heritage Fund and DEFRA, in partnership with Environment Agency and Natural England, who have financially supported this project as part of the Green Recovery Challenge Fund. Without their funding, this project would not have been possible.

Stakeholder Involvement, Expertise and Assistance

CABI

The Centre for Agriculture and Biosciences (CABI) is a not-for-profit inter-governmental development and information organisation focusing primarily on agricultural and environmental issues in the developing world. Specifically, we work with the department for Invasive non-native species and the

members of staff working on biocontrol agents. Our partnership with CABI began when Tees Rivers trust were contracted to conduct the initial HB and JK bio-control field trials in the north. As a result of knowledge, experience and expertise gained as the northern contractor undertaking this work, and with continued support and training from CABI throughout this project, we have gained a reputation as a leading group in the field of HB and JK biological control, and have substantial support for this project from local authorities, interest groups and community groups.
We would like to acknowledge and thank those at CABI, specifically Kate Pollard, Sonal Varia and Suzy Wood and Corin Pratt, for their ongoing support and expertise during this project.

Newcastle University

We would like to acknowledge and thank members of Newcastle University's Invasion Ecology Research Group, Aileen Mill and Zarah Pattison for their support during this project, and Newcastle MBiol students Zoe Gilroy and Beth Williams for their assistance with biocontrol applications/releases and monitoring work, and for data analysis provided by Zoe Gilroy as part of her MBiol dissertation.

Landowners

We would like to thank all of the landowners across the Tees catchment for their ongoing support during the course of this project and for the future. Without their permissions, we would not be able to undertake this work, and we are lucky to work with such supportive landowners.

Executive Summary

The aim of this project is to create a long-term self-sustaining biological control system for one of the most abundant and problematic invasive plants within the Tees catchment. The aim of biocontrol is not to eradicate the invasive species, but control it in a way that it becomes manageable.

Sixteen biological control sites were created to control Japanese knotweed and Himalayan balsam throughout the Tees catchment, with the introduction of psyllid and rust fungus biocontrol agents respectively. All 16 sites were created throughout the duration of this project: 11 Himalayan balsam biocontrol sites were successfully established with rust fungus biocontrol agents as Himalayan balsam plants at all sites exhibited signs of rust fungus infection, and psyllids were detected to be present post release at 5 Japanese knotweed sites. The biocontrol sites will continue to establish and naturally spread and infect other areas affected by Japanese knotweed and Himalayan balsam.

Volunteer activities were conducted during the project to raise awareness and engage members of public about invasive species control through volunteer activities and social media. Two best practice handbooks have been developed to share knowledge and advice to other organisation on using biological control to manage Japanese knotweed and Himalayan balsam.

Partnerships with Newcastle University have benefitted students who have gained field experience and been given the opportunity to conduct their dissertation projects on the biocontrol work conducted. A PhD position has since been created based off of this work.

This work conducted in this project will help to protect heritage in the Tees catchment in the future, improving wellbeing, and helping to make the Tees catchment a better place to live, work and visit.

Introduction

Invasive Species

Invasive non-native species (INNS) are animals or plants that have been introduced (deliberately or accidently) by human activity to an area in which they do not naturally occur, and negatively impact;

the environment, economy and/or human health. Although Global warming and habitat loss take the lion's share of blame for the devastating and continuing reductions in biodiversity, the presence and expansion of invasive non-native species is widely accepted as the third largest reason for declines in species diversity (Forester et al. 2019). It is also accepted that INNS significantly contribute to habitat loss (Linders et al. 2019). Over the past 40-50 years, INNS cost the UK economy over £5 billion (Queen's University Belfast).
With an average of only 53% of biodiversity left in the UK, we are ranked in the bottom 10% of the world's countries and last in the G7 nations (Natural History Museum). Additionally, river habitats are listed on JNCC's UK Biodiversity Action Plan and currently a priority according to the government's 25-year action plan, to ensure clean water and thriving plants and wildlife.

Japanese knotweed and Himalayan balsam

Himalayan balsam and Japanese knotweed are invasive non-native plants that have detrimentally impacted the environment and economy within the Tees catchment for decades, with similar issues mirrored throughout Great Britain. Both species are listed under schedule 9 of the Wildlife and Countryside Act and as such constitutes a significant national conservation threat to native biodiversity and habitats. Natural predators for these invasive non-native plants are not present in Great Britain, consequently enabling both plants to easily out-compete native species, significantly reducing biodiversity and limiting access to valuable and important natural amenities for local communities, interest groups and visitors. Dying back in the autumn, both invasive plants leave large sections of bare and unstable ground vulnerable to erosion by rising river levels, increasing silt loading into waterways. This increased silt has a detrimental impact on habitats within the rivers and streams, such as fish spawning beds and invertebrate habitats. This reduces fish and invertebrate populations, which also affects populations of animals and birds which feed on them.

Japanese knotweed has rightly acquired a reputation as one of the most invasive plants, causing damage to properties, destabilising riverbanks and reducing biodiversity in areas where dense monocultures have grown. Unable to produce viable seeds, Japanese knotweed spreads by vegetative means, with sections of rhizomes as little as 2 mm from an established plant able to produce a new plant and the potential to create new colonies. Japanese knotweed is therefore challenging to control, with chemical spraying the only viable alternative along riverbanks. However, chemical control methods are not suitable within protected areas, and may take several years of treatment and monitoring for successful Japanese knotweed removal to occur.

Each Himalayan balsam plant can produce approximately 600 seeds, many of which germinate or disperse downstream and re-infect cleared sites, quickly creating dense monocultures the following season due to being an annual plant few native plants compete against. CABI research has shown Himalayan balsam monocultures have caused declines in 75% of spider species, 50% of ground dwelling beetles and 25% of other invertebrates. Manual control of HB has not been very effective, as seeds located upstream disperse downstream and re-infect cleared sites, quickly creating dense monocultures the following season due to being an annual plant.

Heritage at risk

Both the natural and cultural heritage of the River Tees and its tributaries are at risk due to the presence of Japanese knotweed and Himalayan balsam. Their presence is directly attributable to reducing biodiversity, ecological and landscape integrity, access, and provision of amenity within the Tees catchment, amongst other factors.

The 2007 review of the UK's Biodiversity Action Plan (BAP) priority species and habitats identified rivers as a priority habitat, and in 2010, a set of criteria was determined to assess and identify specific rivers. The Tees has 21 waterbodies with priority designations based on the BAP species found therein.

These include mammals (water vole, pipistrelle bats and otter), fish (bullhead, Atlantic salmon, brown trout, sea, river and brook lamprey), birds (common reed bunting) and invertebrates (white-clawed crayfish). However, biodiversity within the riparian landscape is detrimentally affected by the ever expanding colonies Japanese knotweed and Himalayan balsam. Over time, both species out-compete native plants due to their early emergence, fast growth and large size, which has knock on effects for other species within the ecosystem. A typical 100m transect of a stretch of the Tees in its middle and lower reaches contains approximately 60-100 species of flora and fauna, whereas a similar sized stretch colonised by invasive plants comprises little else other than the invasive species. Die back of Japanese knotweed and Himalayan balsam plants leave affected riverbanks exposed in winter months, leading to erosion and inputs of sediment to the river. Excessive sediment load has a significant negative impact on in-stream habitats as gravels become smothered and uninhabitable for some invertebrates, which are a vital part of the food chain. Clean, oxygenated gravels are also determining factors in the survival of fish eggs, with dippers and fish relying on healthy invertebrate populations. A drop in fish numbers leaves less availability for piscivorous birds and apex predators such as otters. Otters are also important for controlling the abundance of other invasive species such as mink and American signal crayfish.

Parts of the Tees catchment are ranked amongst the most deprived areas in the UK, both in urban and upland rural areas, with the decline in industry and profitability of farming, the rivers and streams that make up the Tees catchment are an increasingly important economic and leisure resource, with visitors to the area bringing significant income supporting local businesses. The removal of Japanese knotweed and Himalayan balsam will improve the river landscape throughout the Tees by increasing biodiversity, improving access, reducing the risks of property damage and riverbank destabilisation. This will benefit local wildlife, communities, businesses and visitors. Along with other groups, organisations and local authorities, we have delivered sustained programmes of work, manually removing this invasive plant from numerous sites without much success. This project is focused on biocontrol as a method to control Japanese knotweed and Himalayan balsam.

Biological Control

Biological control – or biocontrol – has been used effectively against invasive species for over 100 years. It is the use of living organisms, such as insects or pathogens, to control pest populations. It involves finding natural predators of the target species from its native range to control the invasive species in its non-native range. This requires extensive testing to ensure the biocontrol agent does not negatively affect non-target species in its non-native range, such as the UK. Biological control levels the playing-field with invasive species in their non-native range with native species, by reintroducing some of the specialist natural enemies that naturally help control the invasive species it in its native range. The aim of biocontrol is not to eradicate the invasive species, but control it in a way that it becomes manageable. This form of control is also supported by the GB Non-Native Species Secretariat.

Long-term Biological control of Invasive Non Native Species

The aim of this project is to create a long-term self-sustaining biological control system for two of the most abundant and problematic invasive non-native plants within the Tees catchment area. This project will create the beginnings of a more sustainable, cost effective and efficient method of controlling these invasive plants compared to traditional manual and chemical control strategies. Once biocontrol agents become established, after the project has ended, the infected areas will act as natural sources of dispersal to other areas affected by Japanese knotweed and Himalayan balsam, and infected materials can be collected and re-distributed other areas throughout the catchment. Such measures will facilitate the re-establishment of native flora, increasing biodiversity in the natural environment, improving access, and restoring a safer amenity of local and regional importance. The management method used in this project advantageously requires significantly less manpower to achieve a sustained long-term effect.

Biocontrol will not completely eradicate Japanese Knotweed and Himalayan balsam, but if psyllid and rust fungus establishment occurs, these biocontrol agents will naturally control Japanese Knotweed and Himalayan balsam, making it easier to manage both species and reduce their negative impacts on biodiversity and economic interests.

Project Objectives and Approves Purposes

This report has been produced to evaluate the project objectives and approved purposed as agreed by the Green Recovery Challenge Fund for GRCF2020 Long-term Biological control of Invasive Non Native Species (OM-20-02134). The objectives of this project were to:

- Introduce Biological Control Agents to Selected Sites
- Monitor Biological Control Agents to Ensure Establishment
- Measure Distances Biological Control Agents Expanded from Original Dispersal Sites

The approved purposes of the project were to ensure:

- Heritage will be in better condition
- People will have greater well-being
- The local area will be a better place to live, work or visit

Methods

Site Selection and Set Up

Japanese Knotweed Biocontrol Site Selection and Set Up

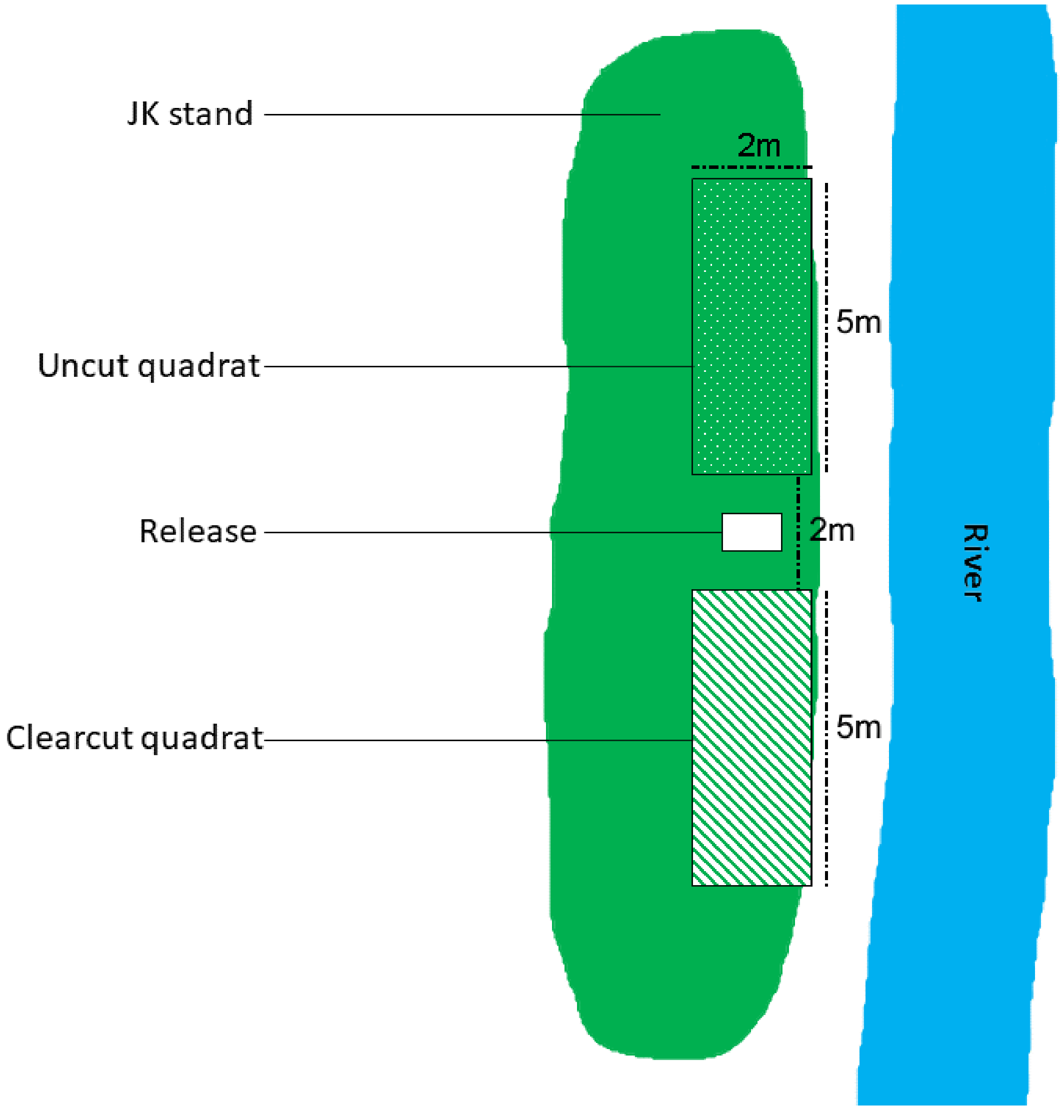
The following CABI criteria were considered when selecting sites for psyllid biocontrol:

- A large and dense stand of Japanese knotweed should be present on the site.
- Anecdotal observations have shown that the psyllids prefer new Japanese knotweed shoots.

Site should be located within a Japanese knotweed stand situated within a riparian habitat, as psyllids survive better in humid habitats similar to those found in the native range in Japan.

Five sites were selected along the River Tees based on the above criteria (see figure x to x in Appendices). Sites were set up by marking out two 5m by 2m quadrats separated by a 2m by 2m section in between with canes within the stand of Japanese knotweed (Figure 1). To see whether psyllids preferred new shoots or older shoots, Japanese knotweed stems in one quadrat were cut above the third node using loppers. The Japanese knotweed plants within the other quadrat were left uncut.

Figure 1. Diagram of Japanese knotweed psyllid site with cut quadrat, uncut quadrat and a central release area. Each site measured a minimum of 12m in length parallel to the river, and 2m deep within a dense stand of Japanese knotweed.



Himalayan Balsam Biocontrol Site Selection and Set Up

The following CABI criteria were considered when selecting sites for rust fungus biocontrol sites:

- The population of Himalayan balsam plants must be large and dense, covering a minimum area of a 10x10m2.
- Himalayan balsam stands also need to be in open areas and not heavily shaded.
- The rust fungus performs better in humid habitats, as humid conditions more closely reflect conditions in the native range.
- Biocontrol sites should be in a stable location to ensure as minimal a chance of being washed away by flooding

Additionally, susceptibility testing is required to confirm which strain of rust fungus will be effective in controlling the population of Himalayan balsam at selected sites, as there is no visual way to distinguish different strains of Himalayan balsam and has been introduced multiple times to the UK. At present, CABI have currently found two rust fungus strains from India and Pakistan.

Eleven sites were originally selected across eight different in the Tees catchment. However, three out of these eight locations were not susceptible to either strain of the rust fungus. Multiple sites were therefore created in the locations which were confirmed to be susceptible to the rust. The amended 11 sites were set up by marking out 5m^2 quadrats where the initial rust fungus inoculation would take place. The 5m2 quadrats were positioned within a stand of Himalayan balsam plants covering areas of at least 10m$^{2.}$

Introduction of Biological Control Agents to Selected Sites

Psyllid Biocontrol Agents

The Japanese knotweed biocontrol agent used in the project is specific species of psyllid (*Aphalara itadori*) which is a small sap sucking aphid reared by the Centre for Agriculture and Bioscience International (CABI). The majority of the psyllids lifecycle is spent on Japanese knotweed. The species survive by sucking sap from Japanese knotweed, stunting the plants growth and reducing its chance to spread. Release of this biocontrol agent had been approved by DEFRA after rigorous testing in quarantine facilities and experimental field trials conducted by CABI.

Psyllid releases

Two psyllid releases were conducted approximately at 5 sites during this project (Table 2). The first release was conducted with a member of staff from CABI, whereby the psyllids were released in a box containing a small Japanese knotweed plant containing 600-800 psyllids per site (Figure 2). This was positioned in the central point between the cut and uncut quadrats, and will remain at the site for 1 year, before being removed by CABI.

The second release was then conducted around 5 weeks later. This release added an additional batch of psyllids to boost the population (300-500 per bread bag). The second batches of psyllids were delivered by next day delivery to be released on the day of arrival. The delivery of psyllids was released on the site as soon as possible to reduce the chance of psyllid mortality which will reduce the likelihood of establishment. The second batches of psyllids were reared on 3 plants per site, with an additional spare plant per site to allow for plant mortality or low egging rates. The plants and psyllids were packaged into bread bags for delivery and transport to site, with an additional sleeve and string (Figure 2). The sleeve and string were secured around one of four delivered plants in each site to protect the psyllids from predators (such as spiders), allowing psyllids residing on the selected plants to lay eggs and develop for a period before removing the sleeve after a few weeks.

(a) (b)

Figure 2. Psyllid batches: (a) Photos of 2nd psyllid delivery via post (b) Placement of bread bag on stand of Japanese knotweed following 2nd release.

Rust fungus Biocontrol Agents

The rust fungus has a complicated 5 stage life cycle (Figure 3). During the spring months spores develop on the undersides of the leaves, spreading throughout stands of Himalayan balsam. As the balsam dies back in the winter, the rust fungus remains in the leaf litter, ready to infect the growing shoots in the spring. Over time the rust continues to infect the stands of Himalayan balsam, reducing the number of seeds produced and consequently reducing the number of plants that will grow.

This biocontrol agent will not completely eradicate Himalayan balsam, as the rust fungus will require it as a host plant its survival. However, due to the effect of the rust fungus on reducing the density of Himalayan balsam plants, competition for resources will also be reduced, giving native species a better chance to grow in these areas, in turn improving biodiversity and reducing the impact of soil erosion. The rust completes its life-cycle on one host.

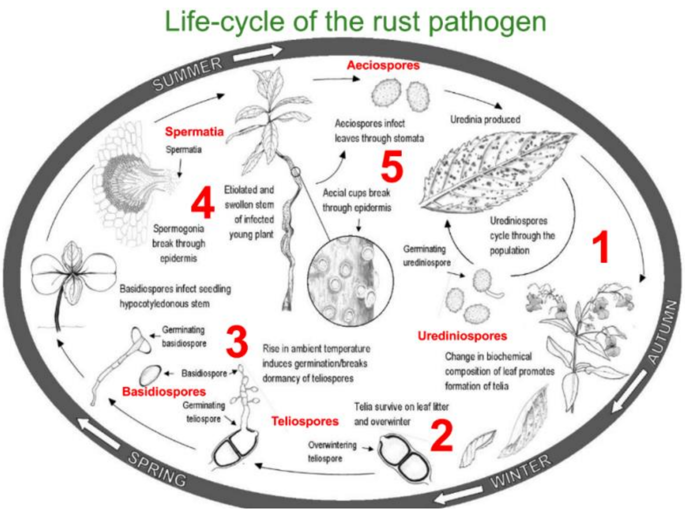


Figure 3. CABI diagram of 5-stage rust fungus life cycle and infection pathway

Rust Fungus Inoculations

Three stages of rust fungus inoculations were conducted during the project to create the Himalayan balsam biocontrol sites. Applications were conducted 4 weeks apart in June, July and August (see Table 1). The first inoculation was undertaken after training was completed with CABI, and after certain criteria have been reached. The criteria were:

- the Himalayan balsam plants had grown to have 3 whorls of leaves on the stem
- The temperature was higher than 10 degrees Celsius during the night when the rust fungus inoculation occurred. If the temperature is lower than 10 degrees, there is a risk that the rust fungus would transition into its overwintering stage and would not spread throughout the site over the Himalayan balsam growing season.

According to the susceptibility testing conducted by CABI, Himalayan balsam sites were inoculated with either the India strain, Pakistan strain, or a mixture of both strains (Table 1). Inoculations were conducted by mixing the rust fungus with water and a surfactant into a spray bottle tested by CABI for the best form of application (Figure 4). After the water, surfactant and rust spores were sufficiently mixed in the spray bottle, the mixture was sprayed as a fine mist to the underside of Himalayan balsam leaves within the $5m^2$ release quadrat at all eleven sites (Figure 5).

Figure 4. (a) CABI training to show how to mix the rust fungus spores, surfactant and water in specially designed spray bottle, and how to apply the rust fungus biocontrol agents to the Himalayan balsam plants; (b) Close up of rust fungus spores in spray bottle prior to mixing with water and surfactant.

The timelines for rust fungus inoculations were conducted as follows:

1. The First Himalayan balsam rust fungus (Pakistan/India/mixed strain) biocontrol agent application was conducted on in June after training with CABI at all 11 sites.
2. The Second Himalayan balsam rust fungus (Pakistan/India/mixed strain) biocontrol agent

application was undertaken and monitoring of rust fungus infection on HB leaves was conducted at 10 sites.

   i. One site (Cleasby) was accidentally destroyed after the first rust fungus application due to miscommunication of the site location with the landowner. Consequently, a new site was set up nearby and was the first application of rust fungus was conducted on the replacement Cleasby site during the second round of rust fungus applications.

3. The third and final Himalayan balsam rust fungus (Pakistan/India/mixed strain) biocontrol agent inoculation was undertaken at 10 sites, alongside monitoring of rust fungus infection. The second application of rust fungus was conducted at the replacement Cleasby site.

Figure 5. Rust fungus biocontrol agents being applied to Himalayan balsam by Tees Rivers Trust staff

Monitoring of Biological Control Agents to Ensure Establishment

During the set up stage of all 16 biocontrol sites, data loggers were placed within the biocontrol site to monitor humidity, temperature and rainfall. This information was collected at the end of the Himalayan balsam and Japanese knotweed growing season and sent to CABI in order to better understand how these environmental variables may affect the success of establishment.

Psyllid Biocontrol Agent Monitoring

An MBiol student from Newcastle University was trained how to monitor for psyllids by observing the leaves where the adults typically reside. Regular monitoring was conducted over 8 sessions from mid-July to the end of September. The psyllids have a 3-stage life cycle (eggs, nymphs and adults) that can be monitored. Monitoring of the different stages will provide data on differing levels of establishment. If eggs are present, it is likely the psyllids are surviving well as reproduction will only occur in suitable conditions (Figure 6.)

To confirm psyllid presence on site, sticky traps provided by CABI were placed at 2m intervals upstream and downstream from the central point of the site to monitor psyllid presence in both the cut and uncut quadrats. The traps were left at each site for 7-10 days. After this period, each sticky trap was collected in individual plastic wallets and labelled as follows:

- Site name - e.g. *Darlington 1*
- Date collected – e.g. *18/09/21*
- Whether it was collected from the cut or uncut quadrat – e.g. *cut/uncut*
- Position placed in site – e.g. *2m/4m/6m upstream/downstream*

The labelled sticky traps were then sent to CABI where the presence/absence of psyllids will be identified by observing the sticky traps under a microscope. Sticky traps were put out to coincide with psyllid releases for the following reasons:

- One week before the second batch of psyllids are released, to see whether psyllids are still present on the site after the first release
- At the end of Autumn, before the Japanese knotweed plants die and the psyllids move up into the canopy where they will overwinter and monitoring will no longer be possible

Sticky traps will also be put out on newly emerged Japanese knotweed plants at the release sites in spring 2022 to see if the psyllids have overwintered successfully.

Initially, Japanese knotweed psyllids were scheduled to be monitored at least monthly using sticky traps at 2m intervals upstream and downstream of the initial release point. However, as monitoring conducted by the MBiol student was less intrusive and more frequent, it was not necessary to use sticky traps more than twice. This was beneficial as the use of sticky traps results in invertebrate mortality, which may have included pysllids and may have reduced the psyllid population size.

Figure 6. Photographs of psyllids in each stage of its life-cycle, and what look for when monitoring. The psyllids are very small and orange/brown colour. Their colouration can help to distinguish psyllids from other insects that might be present on the leaves.
(a) Psyllid eggs (and first instar nymph – bottom left, with legs) under predation by predatory bug for scale. Eggs <1mm and best viewed with a hand lens or magnifying glass. Mostly found on upper surface of leaf, (b) White frass produced by psyllid nymphs at high density. (c) Closer image of psyllid nymphs (mid-instar). Often found at leaf and branch nodes, sometimes on leaves. Can produce white frass, more visible at high density. (d) Psyllid adults. Often found on upper surface of leaf. Orange brown (darker brown in autumn). Can sometimes be found on flowers. Will ping off plant when disturbed.

Rust Fungus Biocontrol Agent Monitoring

Rust infection was recorded using a new app developed by CABI, by taking photographs of the Himalayan balsam leaves to detect rust pustule numbers, rust pustule stage and the level of infection. Monitoring was conducted to observe how the rust fungus life cycle was progressing, to see if plants were becoming infected, and to measure whether infection could be detected outside of the original inoculation area. We monitored 10 plants with the highest infection, and photographed 3 leaves on each infected plant during each stage of monitoring in July, August and September.
The rust fungus can look quite varied in the way it infects Himalayan balsam leaves. The rust pustules can either be small and may cover a large area of the leaf, or pustules may be larger with less leaf coverage (Figure 7).

Figure 7. Examples of rust infection on various leaves. The rust tends to be raised and if touched, a rusty powder comes off the leaves.

Towards the end of the summer, Himalayan balsam starts to die back leaving cane like stems on the ground. The rust fungus infected leaves fall into the leaf litter and enter the overwintering stage. This is difficult to monitor until the following year and monitoring must therefore be conducted in springtime when the new Himalayan balsam shoots start growing. The signs of infection in the spring include twisty stems and small red 'rust' coloured blotches. If these are not present, it is likely the site may need a top up rust inoculation.

Distance Biological Control Measures Expanded from Original Dispersal Sites

As part of the monitoring procedure, we monitored how far the rust fungus/psyllids could be detected from the initial release/inoculation sites. For rust fungus biocontrol sites, this data was recorded and measured during monitoring using CABI app. For psyllid biocontrol sites, this was conducted during monitoring with the MBiol student by searching Japanese knotweed stands adjacent to the stand where psyllids where released.

Approved Purposes

Two Questionnaires were created on Office 365 Forms and sent out to gather feedback from Landowners and members of public about the biocontrol work conducted during this project (see questionnaire questions in Appendices under Questionnaire transcripts).
Data from social media posts published about the biocontrol work throughout the duration of the project was collated to measure social media engagement.

Findings and Conclusions

Evaluation of Project Objectives

Site selection and Set Up

After CABI approval and rust strain susceptibility testing was conducted, 11 Himalayan balsam biocontrol sites and 5 Japanese knotweed biocontrol sites were successfully set up and created.

Introduction of Biological Control Agents to Selected Sites

Biocontrol agents were successfully released/applied at all 16 sites (see Table 1 and 2). However, one site (Cleasby) was accidentally destroyed after the first rust fungus application due to miscommunication of the site location with the landowner. Consequently, a new site was set up nearby and was the first application of rust fungus was conducted on the replacement Cleasby site during the second round of rust fungus applications. This site therefore only received two rust fungus inoculations whereas all other Himalayan balsam sites received the scheduled 3 applications of rust fungus. Despite this, all Himalayan balsam biocontrol sites were observed to have been successfully infected by the rust fungus biocontrol agents.

Table 1. Dates of psyllid releases, approximate number of psyllids released

Site	Biocontrol Agent	Psyllid Strain	No. Psyllids Released	Dates of Release
Sockburn	Psyllid	Mount Aso	600-800 300-500	26.06.21 18.08.21
Eryholme 1	Psyllid	Mount Aso	600-800 300-500	26.06.21 18.08.21
Eryholme 2	Psyllid	Mount Aso	600-800 300-500	26.06.21 18.08.21
Newbus Grange 1	Psyllid	Mount Aso	600-800 300-500	26.06.21 18.08.21
Newbus Grange 2	Psyllid	Mount Aso	600-800 300-500	26.06.21 18.08.21

Table 2. Dates of rust fungus inoculation and monitoring for each Himalayan balsam biocontrol site, and rust infection status of Himalayan balsam biocontrol sites

Site Name	Biocontrol Agent	Rust Strain	Inoculation stage	Inoculation Date
Wycliffe 1	Rust Fungus	India	1st 2nd 3rd	28.06.21 26.07.21 24.08.21
Wycliffe 2	Rust Fungus	India	1st 2nd 3rd	28.06.21 26.07.21 24.08.21
Wycliffe 3	Rust Fungus	Pakistan	1st 2nd 3rd	28.06.21 26.07.21 24.08.21
Wycliffe 4	Rust Fungus	Pakistan	1st 2nd 3rd	28.06.21 26.07.21 24.08.21
Barnard Castle	Rust Fungus	Pakistan	1st 2nd 3rd	28.06.21 26.07.21 24.08.21
Cleasby	Rust Fungus	Pakistan	1st 2nd	26.07.21 24.08.21

Stapleton	Rust Fungus	India	1st 2nd 3rd	28.06.21 26.07.21 24.08.21
Hartlepool 1	Rust Fungus	Pakistan	1st 2nd 3rd	29.06.21 27.07.21 26.08.21
Hartlepool 2	Rust Fungus	Pakistan	1st 2nd 3rd	29.06.21 27.07.21 26.08.21
Ingleby Barwick 1	Rust Fungus	Mixed	1st 2nd 3rd	29.06.21 27.07.21 26.08.21
Ingleby Barwick 2	Rust Fungus	Mixed	1st 2nd 3rd	29.06.21 27.07.21 26.08.21

Monitoring of Biological Control Agents to Ensure Establishment

All 16 sites were monitored multiple times throughout the Japanese knotweed and Himalayan balsam growing seasons. Rust fungus infection was detected at all 11 Himalayan balsam sites, and psyllids were observed to be present at all 5 Japanese knotweed sites (Table 3 and Table 4).

Psyllid Biocontrol Presence

Psyllids were detected during physical monitoring after psyllids had been released at all five sites during the monitoring period, but were not detected during every monitoring session (Table 3). Monitoring psyllid presence was difficult due to their small size and tendency to fly out of sight when leaves were disturbed. Consequently, the data collected may not be representative of the actual psyllid population. It is also difficult to differentiate between individual psyllids by eyesight. Monitoring in this way is beneficial to see whether a population of psyllids is presence/absent on the site, but will not be an accurate way to predict population size. Sticky traps were sent to CABI to be analysed for psyllid presence, but no psyllids were detected on the sticky traps.

Table 3. Table showing the results of monitoring each site and the date the site was monitored and whether psyllids were present.
**Y = Psyllid Presence - either seen directly or presence of eggs detected.*
**N = Psyllid Absence - Important to note that this does not mean psyllids were not present, but instead reflects that psyllid were not detected during monitoring (psyllids can fly and may travel to other stands of Japanese knotweed in the area, or may simply have been missed at the time of monitoring).*

Date Monitored	Site 1	Site 2	Site 3	Site 4	Site 5
24/06/21	First Psyllid Release				
15/07/21	Y	Y	Y	Y	Y
29/07/21	N	Y	Y	N	N
05/08/21	Y	Y	Y	N	N
12/08/21	N	N	Y	Y	Y
12/08/21	Sticky Traps Set Up				
18/08/21	Sticky Traps Collected				
19/08/21	Second Psyllid Release				
03/09/21	Y	N	Y	N	N
08/10/21	N	N	Y	N	Y

22/10/21	N	N	N	N	N
15/11/21	Sticky Traps Set Up				
26/11/21	Sticky Traps Collected				
01/12/21	Psyllids Overwintering in Trees				

Rust Fungus Biocontrol Presence

The final monitoring stage rust fungus infection on Himalayan balsam leaves were conducted at all 11 sites. As the sites were located in different areas within the Tees catchment, the Himalayan balsam population had unfortunately died back at a few sites before the final monitoring could take place effectively. However, all sites exhibited infected Himalayan balsam plants during the first and second stages of monitoring (Table 4).

The average percentage of plants infected by rust fungus in a marked area of 1m2 within the rust fungus inoculation areas can be seen in Figure 8. The highest percentage of plants observed to have infected by rust fungus in a marked area of 1m2 was at Wycliffe 1 (70.3%) in comparison to the lowest percentage of plants observed to have infected by rust fungus in a marked area of 1m2 at Wycliffe 2 (21.59%). Although the same strain of rust fungus (India) was applied to both Wycliffe 1 and Wycliffe 2, other environmental variables such as shade likely impacted the spread or level of infection recorded at each site.

See Figures x to x in the Appendices for infection results for all Himalayan balsam rust fungus biocontrol sites. Overwintering monitoring will be conducted in May to observe whether newly emerging Himalayan balsam seedlings have been infected by rust spores that will have remained in the Himalayan balsam leaf litter when the plants died back in autumn and persisted throughout the winter period.

Table 4. Rust fungus infection results recorded after each stage of monitoring ** Himalayan balsam plants had died back before third monitoring was conducted. **Cleasby received two stages of monitoring as it was not possible to conduct a third stage due to time of year and balsam died back.*

Site Name	**Biocontrol Agent**	**Rust strain**	**Monitoring Date**	Infection at site (yes/no)	Number of plants within the marked area (1m2)	Number of plants infected in marked area (1m2)	Percentage of plants infected in marked area (1m2)	**First stage of rust fungus establishment observed (yes/no)**
Wycliffe 1	Rust Fungus	India	26.07.21	Yes	18	2	11%	Yes
			24.08.21	Yes	9	9	100%	
			27.09.21	Yes	4	4	100%	
Wycliffe 2*	Rust Fungus	India	26.07.21	Yes	15	4	27%	Yes
			24.08.21	Yes	21	8	38%	
			27.09.21	N/A	N/A	N/A	N/A	
Wycliffe 3	Rust Fungus	Pakistan	26.07.21	Yes	12	5	0.42	Yes
			24.08.21	Yes	5	5	100%	
			27.09.21	Yes	6	3	50%	
Wycliffe 4	Rust Fungus	Pakistan	26.07.21	Yes	19	8	42%	Yes
			24.08.21	Yes	10	10	100%	
			27.09.21	Yes	8	3	0.38%	
Barnard Castle*	Rust Fungus	Pakistan	26.07.21	Yes	91	30	33%	Yes
			24.08.21	Yes	20	3	15%	

			27.09.21	N/A	N/A	N/A	N/A	
Cleasby**	Rust Fungus	Pakistan	24.08.21	Yes	25	25	100%	Yes
			27.09.21	Yes	7	2	29%	
Stapleton	Rust Fungus	India	26.07.21	Yes	16	6	38%	Yes
			24.08.21	Yes	12	12	100%	
			27.09.21	Yes	39	21	54%	
Hartlepool 1	Rust Fungus	Pakistan	27.07.21	Yes	10	10	100%	Yes
			26.08.21	Yes	6	2	33%	
			28.09.21	Yes	8	5	63%	
Hartlepool 2	Rust Fungus	Pakistan	27.07.21	Yes	21	4	19%	Yes
			26.08.21	Yes	12	4	33%	
			28.09.21	Yes	4	3	75%	
Ingleby Barwick 1	Rust Fungus	Mixed	27.07.21	Yes	13	5	38%	Yes
			26.08.21	Yes	13	6	46%	
			28.09.21	Yes	12	4	33%	
Ingleby Barwick 2	Rust Fungus	Mixed	27.07.21	Yes	10	4	40%	Yes
			26.08.21	Yes	35	35	100%	
			28.09.21	Yes	15	10	67%	

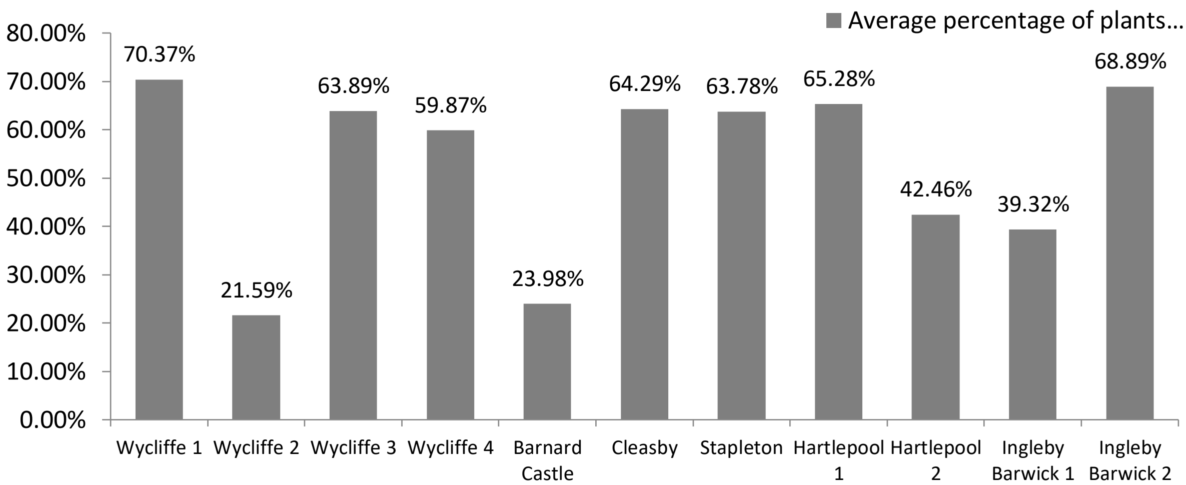


Figure 8. Average percentage of plants infected with rust fungus spores within $1m^2$ marked areas for each Himalayan balsam biocontrol site

Distance Biological Control Measures Expanded from Original Dispersal Sites

Rust fungus infection was monitored on three occasions at four week intervals after each inoculation (Table 5). Rust fungus infection on Himalayan balsam plants was observed to have spread from the original dispersal site in 8 of the 11 Himalayan balsam biocontrol sites (Table 5) The distance rust fungus infection was measured to have spread from the original application sites varied from 0.5m to 20m.

Variables such as humidity and wind speed on the day rust fungus biocontrol agents were released may have affected the spread of the rust fungus spores, as well as other environmental variables such as temperature and light intensity. Where rust fungus infection spread was detected outside of the initial release quadrat during the second stage of monitoring, but not in the third stage of monitoring, it is possible that infected plants may have been trampled accidentally and died. Alternatively, as the first rust fungus inoculation was delayed by low evening temperatures and thus subsequent inoculations and monitoring were also delayed, some Himalayan balsam plants may have died before the third monitoring could be conducted. The location of the biocontrol sites throughout the catchment will have also affected the rate at which Himalayan balsam plants died, as Himalayan balsam populations were observed to emerge earlier and grow at different rates throughout the catchment.

As all Himalayan balsam sites were successfully infected, the life cycle of the rust fungus will enable a continued process of establishment will occur, with rust fungus spores naturally spreading further from the initial inoculation site over the next few years.

Table 5. Rust fungus infection spread outside of release area results recorded after each stage of monitoring ** Himalayan balsam plants had died back before third monitoring was conducted. **Cleasby received two inoculations due to initial site being destroyed: a third rust fungus inoculation was not possible due to time of year and balsam died back.*

Site Name	Monitoring stage	**Monitoring Date**	Infection at site (Yes/No)	Infection found on leaves and branches (Yes/No)	Spread outside release area (Yes/No)	Maximum spread (m)
Wycliffe 1	1st	26.07.21	Yes	Yes	No	0
	2nd	24.08.21	Yes	Yes	No	0
	3rd	27.09.21	Yes	Yes	Yes	2.0
Wycliffe 2	1st	26.07.21	Yes	Yes	No	0
	2nd	24.08.21	Yes	Yes	No	0
	3rd *	27.09.21	N/A	N/A	N/A	N/A
Wycliffe 3	1st	26.07.21	Yes	Yes	Yes	2.0
	2nd	24.08.21	Yes	Yes	No	0
	3rd	27.09.21	Yes	Yes	Yes	2.0
Wycliffe 4	1st	26.07.21	Yes	Yes	Yes	4.5
	2nd	24.08.21	Yes	Yes	No	0
	3rd	27.09.21	Yes	Yes	No	0
Barnard Castle	1st	26.07.21	Yes	Yes	No	0
	2nd	24.08.21	Yes	Yes	No	0
	3rd *	27.09.21	N/A	N/A	N/A	N/A
Cleasby	1st	24.08.21	Yes	Yes	No	0
	2nd **	27.09.21	Yes	Yes	No	0
Stapleton	1st	26.07.21	Yes	Yes	No	0
	2nd	24.08.21	Yes	Yes	Yes	20.0
	3rd	27.09.21	Yes	Yes	No	0
Hartlepool 1	1st	27.07.21	Yes	Yes	No	0
	2nd	26.08.21	Yes	Yes	No	0
	3rd	28.09.21	Yes	Yes	Yes	1.0
Hartlepool 2	1st	27.07.21	Yes	Yes	No	0
	2nd	26.08.21	Yes	Yes	Yes	1.0
	3rd	28.09.21	Yes	Yes	Yes	2.0
Ingleby Barwick 1	1st	27.07.21	Yes	Yes	No	0
	2nd	26.08.21	Yes	Yes	Yes	1.5
	3rd	28.09.21	Yes	Yes	No	0
Ingleby Barwick 2	1st	27.07.21	Yes	Yes	Yes	0.5
	2nd	26.08.21	Yes	Yes	No	0
	3rd	28.09.21	Yes	Yes	No	0

Evaluation of Approved purposes

Heritage Will Be In Better Condition

The establishment of long-term biological control areas for these invasive non-native plants will help to reduce their stranglehold on locally important natural amenities, and will facilitate the re-establishment of native flora, increasing biodiversity in the natural environment, improving access, and restoring a safer amenity of local and regional importance. This project has successfully introduced biocontrol agents to 16 sites throughout the Tees catchment which were monitored at various stages throughout the project duration. These sites will directly benefit the areas surrounding the biocontrol sites created during this project as the sites establish further, and will indirectly benefit the Tees catchment as a whole as the biocontrol sites naturally spread to other areas affected by Himalayan balsam and Japanese knotweed, and may be used as sources of biocontrol agents that may be purposefully translocated to other problem areas (Table 6). Biological control of both Japanese knotweed and Himalayan balsam saves time and money in the long-term: if the biocontrol sites continue to establish and spread naturally, this method of control is economically better as a long-term solution than traditional methods of Himalayan balsam and Japanese knotweed biocontrol.

A trial translocation of a small amount of infected Himalayan balsam leaves was conducted to see whether this could infect a population of Himalayan balsam in a different area to the biocontrol sites. Five infected leaves were taken from a biocontrol site that was created in Hutton Rudby three years ago during the initial field trials conducted by CABI. The leaves were translocated to a population of Himalayan balsam located downstream and situated on the opposite side of the river bank of the source site. The rust pustules present on the infected leaves were wiped across uninfected leaves of Himalayan balsam plants within a $1m^2$ area marked by canes. The leaves were then attached to Himalayan balsam plants with rope within the $1m^2$ area. The site was then monitored a few weeks later to see if this had successfully infected any plants: the plants that were wiped with the infected leaves had become infected. This shows that in future, when the Himalayan balsam sites created during this project have been given a few years to naturally spread and establish further, infected leaves may be translocated to other problem areas. However, it should be noted that this may not always work due to the different rust fungus strains. As susceptibility testing was not conducted for this translocation, it was by chance that this trial translocation was successful, as the new population was susceptible to the same strain of rust fungus as the source site in Hutton Rudby.

Table 6. Area of land directly and indirectly benefitting in locations where biocontrol sites were created (km^2)

Site	Species	Biocontrol Agent	Area of Land Directly benefitting (km^2)	Area of Land Indirectly benefitting (km^2)
Wycliffe 1 Wycliffe 2 Wycliffe 3 Wycliffe 4	Himalayan balsam	Rust Fungus	13.4	2102.9
Hartlepool 1 Hartlepool 2	Himalayan balsam	Rust Fungus	35.3	2102.9
Ingleby Barwick 1 Ingleby Barwick 2	Himalayan balsam	Rust Fungus	9.6	2102.9
Stapleton	Himalayan balsam	Rust Fungus	19.4	2102.9
Cleasby	Himalayan balsam	Rust Fungus	38.7	2102.9
Barnard Castle	Himalayan balsam	Rust Fungus	2.3	2102.9

Newbus Grange 1 Newbus Grange 2	Japanese knotweed	Psyllid	46.9	2102.9
Eryholme 1 Eryholme 2	Japanese knotweed	Psyllid	34.5	2102.9
Sockburn	Japanese knotweed	Psyllid	25.1	2102.9

Himalayan balsam ‘balsam bashing’ volunteer sessions were also organised to clear areas of Himalayan balsam where neither rust strain are currently susceptible. The use of biocontrol agents along with regular sessions of balsam pulling with the community means there is higher sustainability of control long term. These sessions helped to raise awareness on the impact of invasive species and the importance of controlling them.

Throughout the project other organisations have learned of our work through social media posts, press releases, presentations and recommendations from CABI. As such, we have been able to provide advice and best practice knowledge to Angling Clubs, AONBs, Rivers Trusts and National Parks outside of the Tees catchment (Table 7) that are looking to begin establishing biocontrol agents to control Himalayan balsam and Japanese knotweed. This shows that the work conducted in this project has been important not only within the Tees catchment, but over a wider region national. Additionally, the information gained from the project is of national importance to CABI, as the biocontrol sites created by Tees Rivers Trust during this project represent 40% of all CABI sites established in 2021. CABI have thus published the work conducted during this project in annual summary of biocontrol work.

Landowners who responded to the Landowner questionnaire either agreed or strongly agreed that the early stages of the biocontrol work conducted so far has been beneficial, or that they did not know (see Figure 9). Where landowners answered that they were unsure about the success off the biocontrol agent so far, this is likely because the effects of biocontrol management can take time. However, despite this, all landowners who answered the questionnaire would consider using biocontrol agents to control invasive species on their land in the future. Questionnaire answers have been submitted with the Completion report.

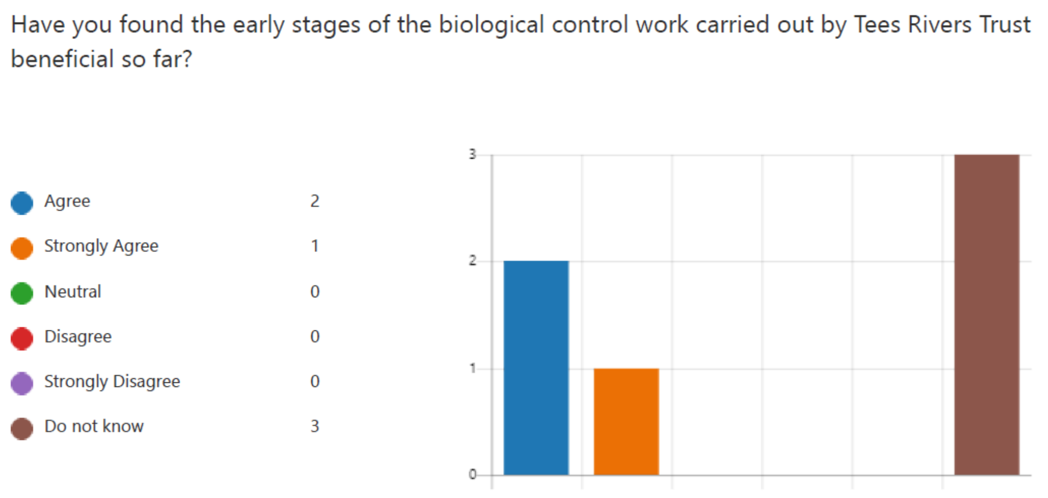


Figure 9. Questionnaire analysis from landowner questionnaire: (a) Landowner opinions on whether they have found the early stages of biological control work to have been successful so far; (b) Landowners who would consider using biological control agents to manage INNS on their land in the future

Table 7. Number of activities and events conducted throughout project to achieved project objectives and approved purposes

Activity/Event	Number of events
Monitoring psyllid presence	42
Training session on biocontrol agent application	11
Biocontrol application and monitoring	33
Knowledge sharing meeting with Brecon Beacons National Park	1
Knowledge sharing meeting with Anglers	2
Training session - showing local volunteer and landowner how to apply and monitor the biocontrol agent.	1

People Will Have Greater Well-being

Volunteering

We have enabled local people to socialise, meet like-minded people and spend time outside in nature by organising volunteer days outside along the river to assist with manual Himalayan balsam management, AKA Balsam Bashes (Table 8). Volunteer events organised to conduct Balsam Bashes during this project have also benefited older and isolated individuals who use volunteering to improve their mental wellbeing and to socialise. This has also benefitted anglers and other river users by clearing areas of Himalayan balsam where neither rust strain are currently susceptible, improving access for fishing, walking, and providing safer access/exit points for canoeist/kayakers.
The establishment and continued spread of psyllids and rust fungus from sites created in this project

will further improve biodiversity, ecological and landscape integrity, access, and provision of amenity for local communities and visitors.

Table 8. Number of volunteer activities conducted by local people throughout project to improve well-being whilst adding value to the project

Activity/Event	Number of events
Manual removal by hand-pulling Himalayan balsam with volunteers , AKA balsam bashing	2
Photography and rust fungus biocontrol monitoring volunteer opportunity	4

Social Media

Older and/or isolated people have also been given the opportunity to engage with each other via social media posts about the biocontrol project work. This has been especially important during the Covid-19 pandemic when older and/or more vulnerable people have sought out virtual communication to feel less isolated. Across the duration of the project, 75 posts and 44 stories have been published on Tees Rivers Trusts social media platforms (Facebook, Instagram, Twitter, LinkedIn, YouTube, website log) to engage people, encourage conversation about the environment, and to raise awareness about invasive species.
Social media posts reached 17246 people virtually, and received 774 reactions or likes, showing that members of public viewing our posts on social media platforms were interested in the biocontrol work being conducted (Table 9).

Table 9. Summary of Tees Rivers Trust social media engagement relating to posts about this project

Social Media Platform	Posts and/or stories	Reach	Engagement	Reactions or likes	Comments	Shares
Facebook	119	17246	1350	481	37	47
Instagram	36	N/A	N/A	257	6	N/A
Website Blog	9	N/A	135	34	N/A	N/A
YouTube	2	N/A	34	2	N/A	N/A

Feedback from the community questionnaire was positive. The community questionnaire was completed by 30 members of public. 97% of respondents agreed that they had gained a better understanding of the negative impacts of invasive species because of this project, 87% of respondents thought that the project had changed the way people think or feel about Japanese knotweed and Himalayan balsam (of the environment in general), and 80% of respondents confirmed they have a better understanding of Japanese knotweed and Himalayan balsam biocontrol work due to this project (Figure 10). Questionnaire answers have been submitted with the Completion report.

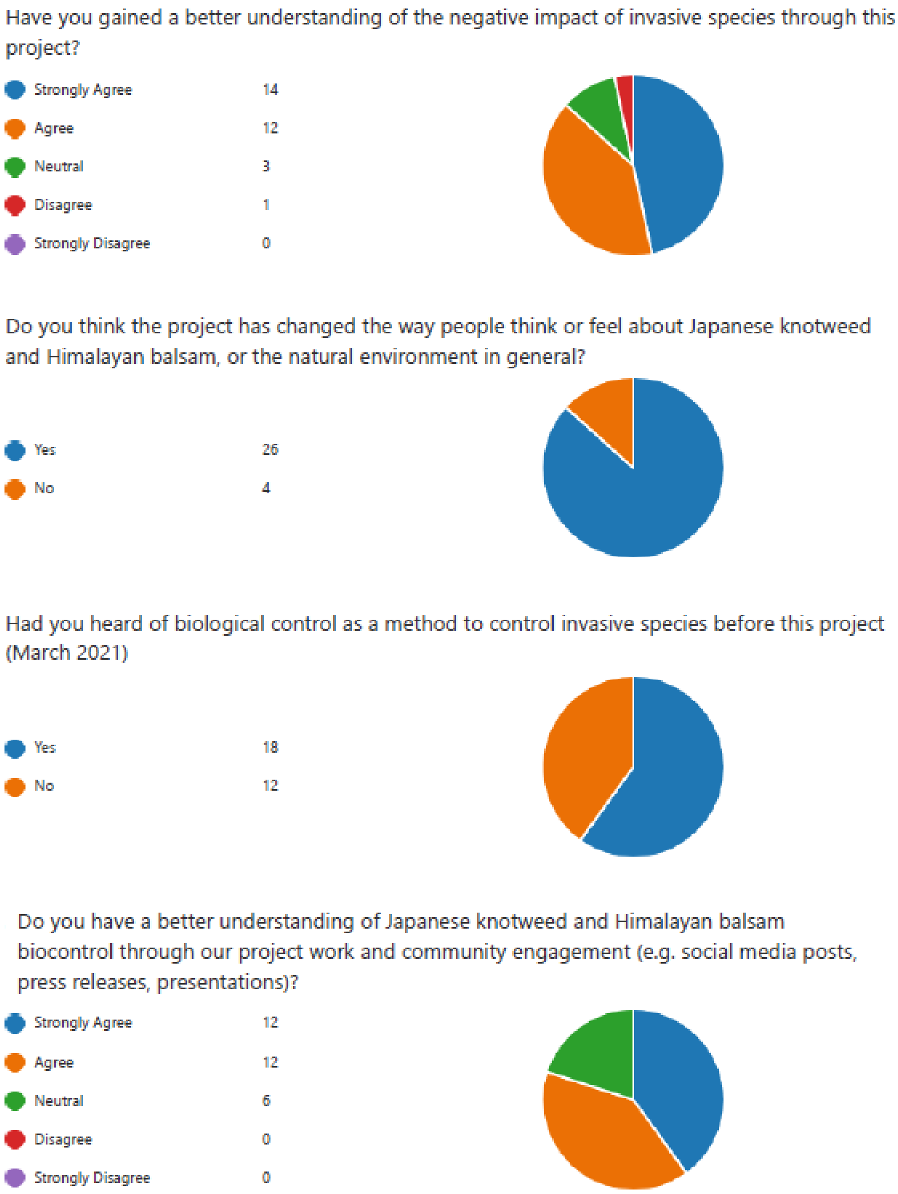


Figure 10. Community questionnaire responses relating to questions based on invasive species knowledge, and understand biological control

The Local Area Will Be A Better Place to Live, Work or Visit

Biodiversity, Ecological and Landscape Integrity, Access, and the Provision of Amenity

The presence of Himalayan balsam and Japanese knotweed are directly responsible for reducing biodiversity, ecological and landscape integrity, access, and provision of amenity on a national basis. The river corridors of Tees has long been a source of amenity and enjoyment for residents and visitors alike, contributing substantially to the health and wellbeing of people within the region, as well as being a source of economic input, adding to the wealth of the area. The establishment and continued spread of psyllids and rust fungus from biocontrol sites created in this project will improve biodiversity, ecological and landscape integrity, access, and the provision of amenity for local communities and visitors. Vegetation surveys have been conducted throughout the duration of the project, and changes in vegetation cover in the biocontrol sites will be monitored after the project end date. These surveys will be conducted to monitor changes in biodiversity as the biocontrol sites continue to establish, spread and naturally control the Japanese knotweed and Himalayan balsam populations throughout the Tees catchment.

This project has enabled local people to socialise, meet like-minded people and spend time outside in nature by organising volunteer days outside along the river to assist with manual Himalayan balsam management. This has also benefitted anglers and other river users by clearing areas of Himalayan balsam where neither rust strain are currently susceptible, improving access for fishing, walking, and providing safer access/exit points for canoeist/kayakers.

University research – benefitting students and the wider public through beneficial environmental research

This project has provided an opportunity for a University research group to get involved with the early stages of cutting edge scientific approach to more naturally control two of the most problematic invasive non-native species in the UK, which will benefit future biocontrol work through research to further understand and predict the spread of psyllids throughout Japanese knotweed populations, and Rust fungus through Himalayan balsam populations. The project has also given students an opportunity to collect data for their MBiol dissertation projects, increasing their skill-sets and gaining field experience within the environmental sector to improve their level of employability post-graduation. The students also learned about the science of biological control which benefitted their studies, and has enabled them to be able to assist with additional releases and monitoring in future for the long-term establishment of the rust fungus biocontrol agent.

Additionally, Newcastle University applied for a IAPETUS2 project studentship for a PhD position in collaboration with Tees rivers Trust, CABI and the University of Stirling, based on the biocontrol work conducted during this project to assess the in-situ drivers of rust fungus infection success of I. glandulifera (Himalayan balsam) and develop a modelling and monitoring framework to determine the natural dispersal efficacy of the rust fungus to other invaded sites (see IAPETUS2 Project Submission document submitted for further details). Specifically, the project objectives of the PhD are to:

- Determine the key environmental variables that impact the efficacy of rust fungus infection and survival in-situ.
- Undertake an assessment of the impact of the rust fungus on I. glandulifera seed production as a determinant of biological control success in managing invaded areas.
- Determine the efficacy of drone imagery in assessing reduction in population size of infected I. glandulifera populations and determining infection status of I. glandulifera populations.
- Assess the natural dispersal capabilities of the rust fungus using a spatial modelling approach

The work conducted by Newcastle University researchers and student will help to develop spatial and temporal modelling approaches that may be used to analyse Himalayan balsam management at a regional and national scale.

Lessons Learned & Knowledge Sharing

Best Practice and knowledge sharing

In order to share best practice knowledge, advice and to share lessons learned from experience gained working with CABI prior to and during this project, we have produced the first edition of two best practice handbooks on Himalayan balsam biocontrol and Japanese knotweed biocontrol. The handbooks provide information and case study of Tees Rivers Trust's process to create the biocontrol sites that we currently have throughout the catchment. The best practice handbooks will be made freely available to download on our website, and will be shared with other organisations. The contents of the best practice handbook are based off Tees Rivers Trust's experience of the psyllid biocontrol of Japanese knotweed from 2020-2021, and as research and experience progress, the methods and outcomes may vary and new versions of the handbook will be revised and available publicly.

Site selection

Initially five sites were changed locations due to being unsusceptible to the strains of the rust fungus. We were able to relocate these rust funguses to other sites but still have balsam issues at the other sites. Meaning we have had to have alternative methods of control (such as holding volunteer events to remove the balsam)

Marking Biocontrol Sites

Marking sites and adding signs out about the work being undertaken opens the risk of having the site destroyed or messed with, including data loggers being taken. However, there are also risks to not having signs and markings on the site, including people removing the Himalayan balsam from the area non-the-wiser to it being a biocontrol site. This is something that needs to be thought about and will differ on a case-by case basis (see first draft of Himalayan balsam Biocontrol Best Practice Handbook). One way in which we easily located release/inoculation locations is by using what3words. What3words is an app that has marked out the globe in 3m2 each with their own 3 words. We use this app frequently for our invasive species work.

Biocontrol Monitoring

There are pros and cons to using sticky traps over other forms of monitoring methods used in during the project. Pros include; psyllids caught on sticky traps will not be mistaken for other species, using sticky trap is less time-consuming than monitoring for psyllids by eye. The Cons of this method include; non-target species (such as other invertebrates and even birds) may be caught, psyllids caught on traps will be removed from the population, which is not desirable before the population has established. To reduce the risk of bird mortality, silver tape was attached to sticky traps attached to Japanese knotweed plants in order to act as a deterrent towards bird from approaching sticky traps (Figure 11).

Figure 11. Silver tape attached to centre of sticky trap to deter birds from approaching sticky traps with the aim to reduce the risk of bird mortality from birds getting stuck on the trap

Site destruction

The site location was on private land; however, the adjacent bank across the river is publicly accessible. There were a few concerns initially with this site, as we found that some of the original Himalayan balsam patch had been burnt by a small fire, as well as tent pegs were found nearby. We carried on with the site, releasing the first inoculation. As we returned to the site to place data loggers, we found that the site had unfortunately been accidentally destroyed by the landowners. Thankfully, we had a control site available to place the other 2 inoculations. Although we had sent a map of the biocontrol location, we would suggest taking the landowners to see exactly where the biocontrol site is as well as sending a map to avoid any mistakes.

Losing the Cleasby site after 1 round of inoculation occurred due to miscommunication about site location with landowner. As a recommendation for the future, it is advised to take landowners to the exact location of biocontrol sites, as although we had sent maps of the location of the site, the site was accidentally destroyed. Fortunately, this occurred after one dose of the rust fungus application. We were therefore able to use what was initially selected as a ‘control’ site for the MBiol student’s dissertation project to create a replacement biocontrol site that was inoculated twice with the rust fungus.

Partnerships

Although our partnership with Newcastle University has worked brilliantly during this project, one student decided that they no longer wanted to conduct their dissertation research on the psyllid biocontrol work. Consequently, we missed out on retrieving some psyllid monitoring data that could have been beneficial. In future would have recommended collecting multiple copies of the data.

Health and Safety

A number of potential hazards should be acknowledged when undertaking biocontrol work and risk assessments should be completed before undertaking work. Although Japanese knotweed is found growing in a variety of habitats, it tends to grow near other plants that may cause injuries, such as common nettles and bramble. Giant hogweed is another problematic invasive species within the Tees catchment, and is present at 3 out of our 5 psyllid biocontrol sites. We therefore recommend that gloves should be worn when monitoring biocontrol sites. Management of such species may be required to ensure safe access to your biocontrol site, and this should be considered when planning biocontrol site locations. For example, giant hogweed is spot sprayed around our biocontrol sites. However, this must be conducted carefully ensuring drift from herbicide spraying will not affect the Japanese knotweed stands within the biocontrol site area.

When choosing a site, accessibility must be considered. Large stands of Japanese knotweed or Himalayan balsam may be found that would be ideal for biocontrol releases, but with limited, poor and/or unsafe access. Selecting a site where access is limited and/or unsafe should be avoided, due to the number of visits required for each site to undertake monitoring. For example, in this project where our biocontrol sites reside along the River Tees, many stands of Japanese knotweed and Himalayan balsam are adjacent to steep banks and are not easily accessible. Additionally, as both species affect soil quality and increase the risk of river bank erosion, caution should be taken be in case riverbanks are not as stable as they appear.

Photographic Records

Please see BINNS Photographic Record of Project Activities document submitted with Completion report for further photographic records of project stages.

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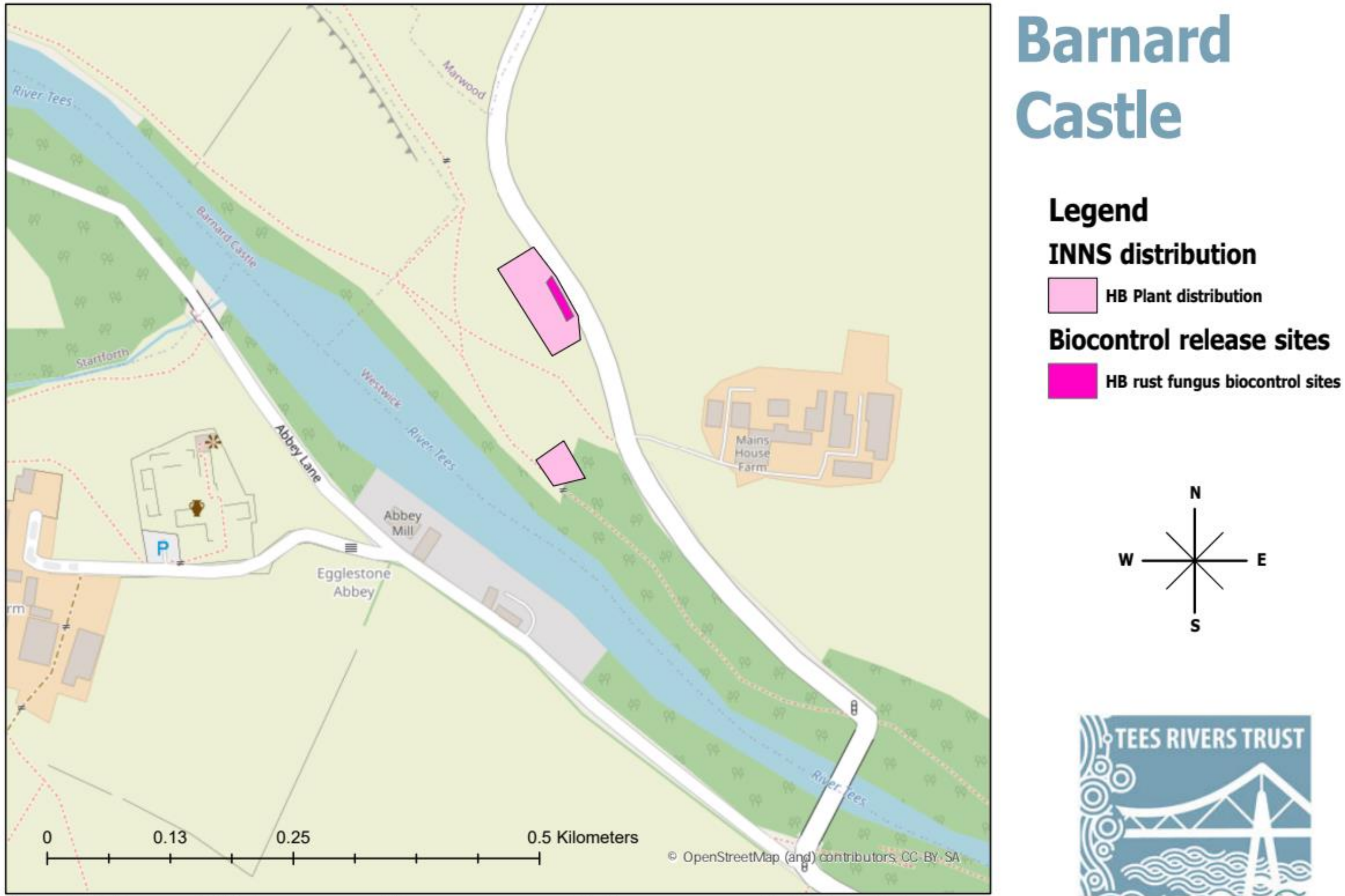
Appendices

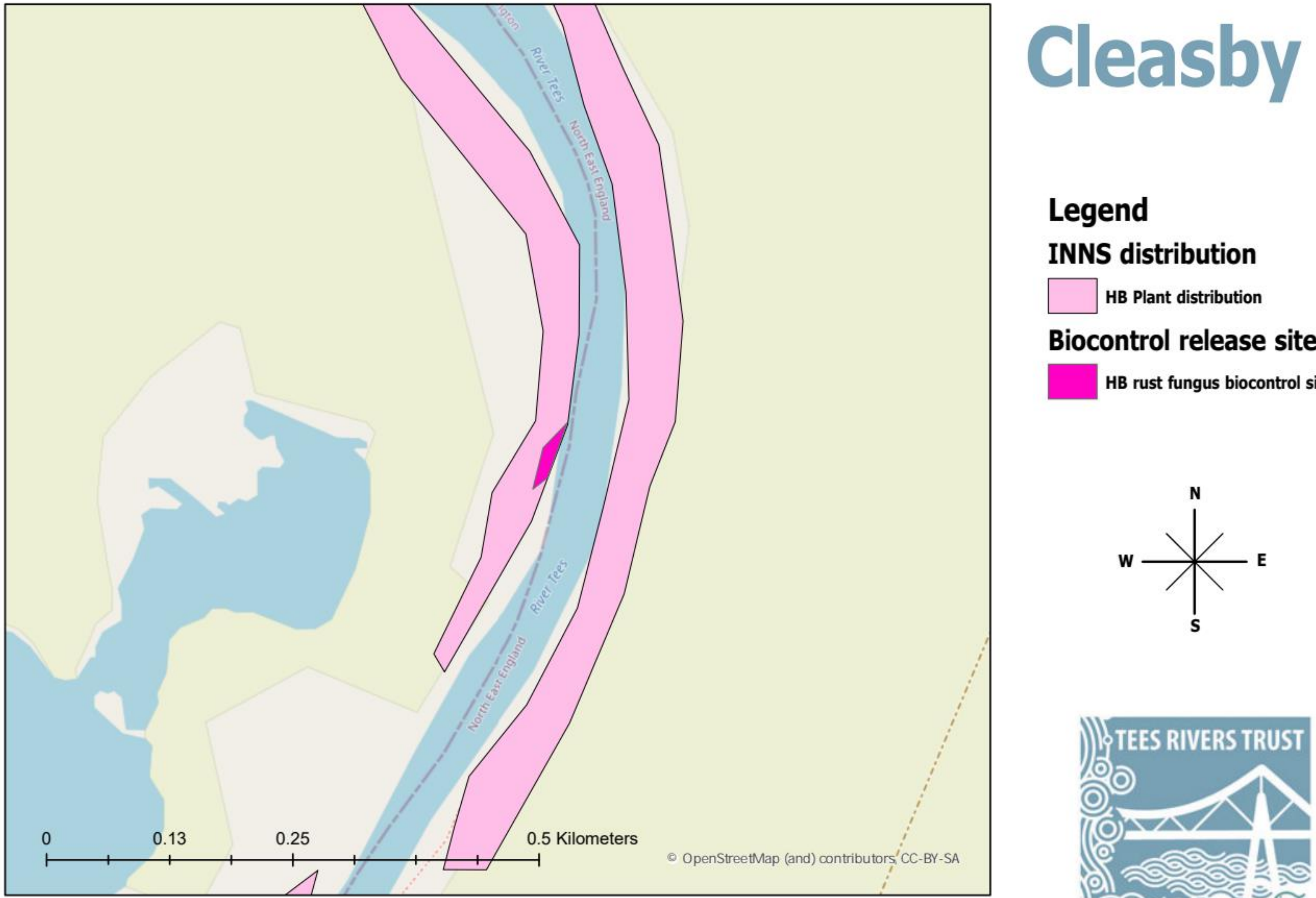
Site maps

Himalayan balsam biocontrol sites



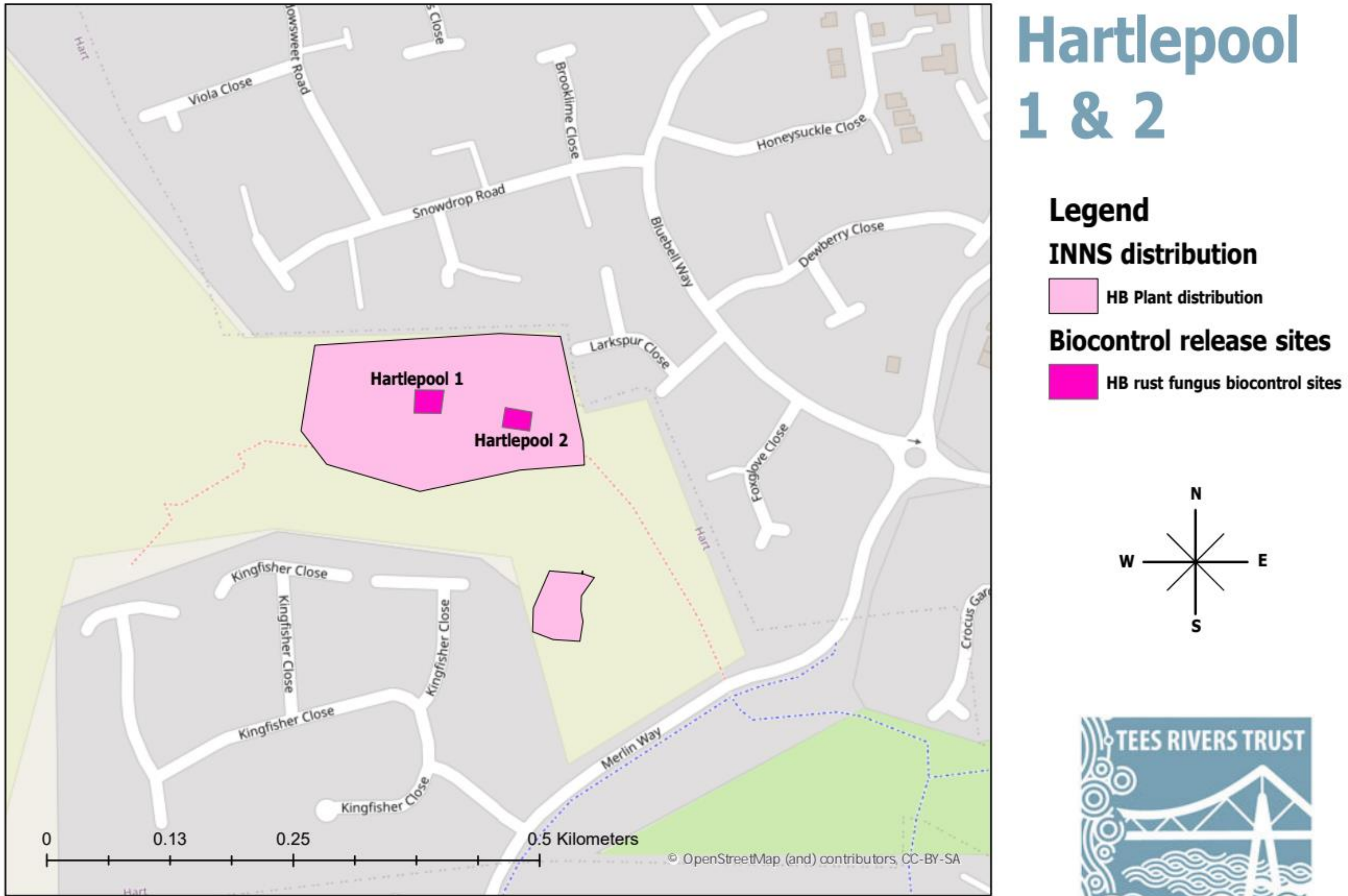
Biocontrol Site	Habitat	River	Strain	First Release Date
Barnard Castle	Grassland	River Tees	Pakistan	28.06.21

Figure x. Map of Himalayan balsam rust fungus biocontrol sites Barnard Castle, with accompanying table of rust fungus inoculation dates for each site and strain of rust fungus applied.



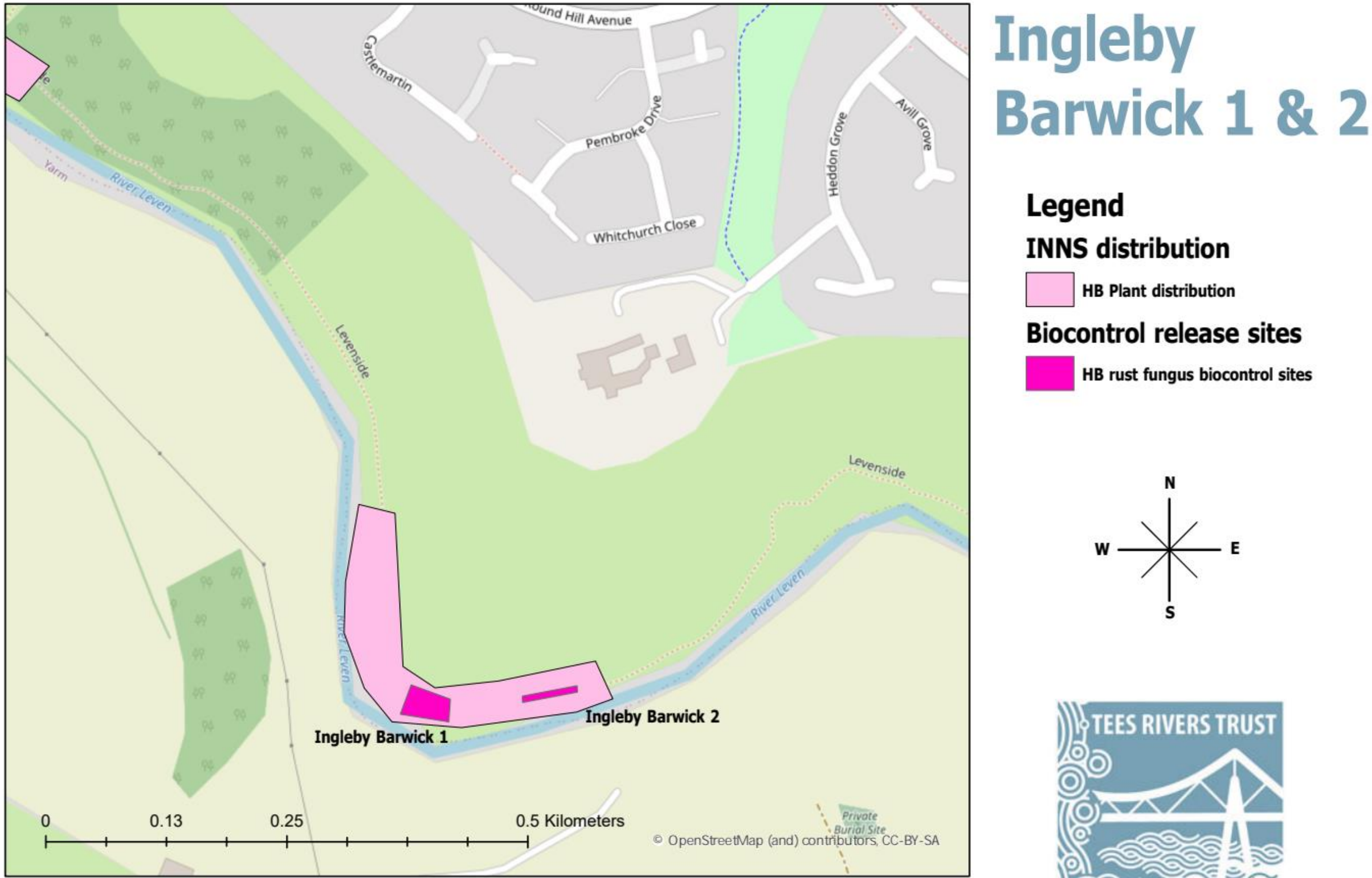
Biocontrol Site	Habitat	River	Strain	First Release Date
Cleasby	River Bank	River Tees	Pakistan	28.06.21

Figure x. Map of initial Himalayan balsam rust fungus biocontrol site Cleasby, with accompanying table of rust fungus inoculation dates for each site and strain of rust fungus applied. Replacement site can be seen in Figure x.



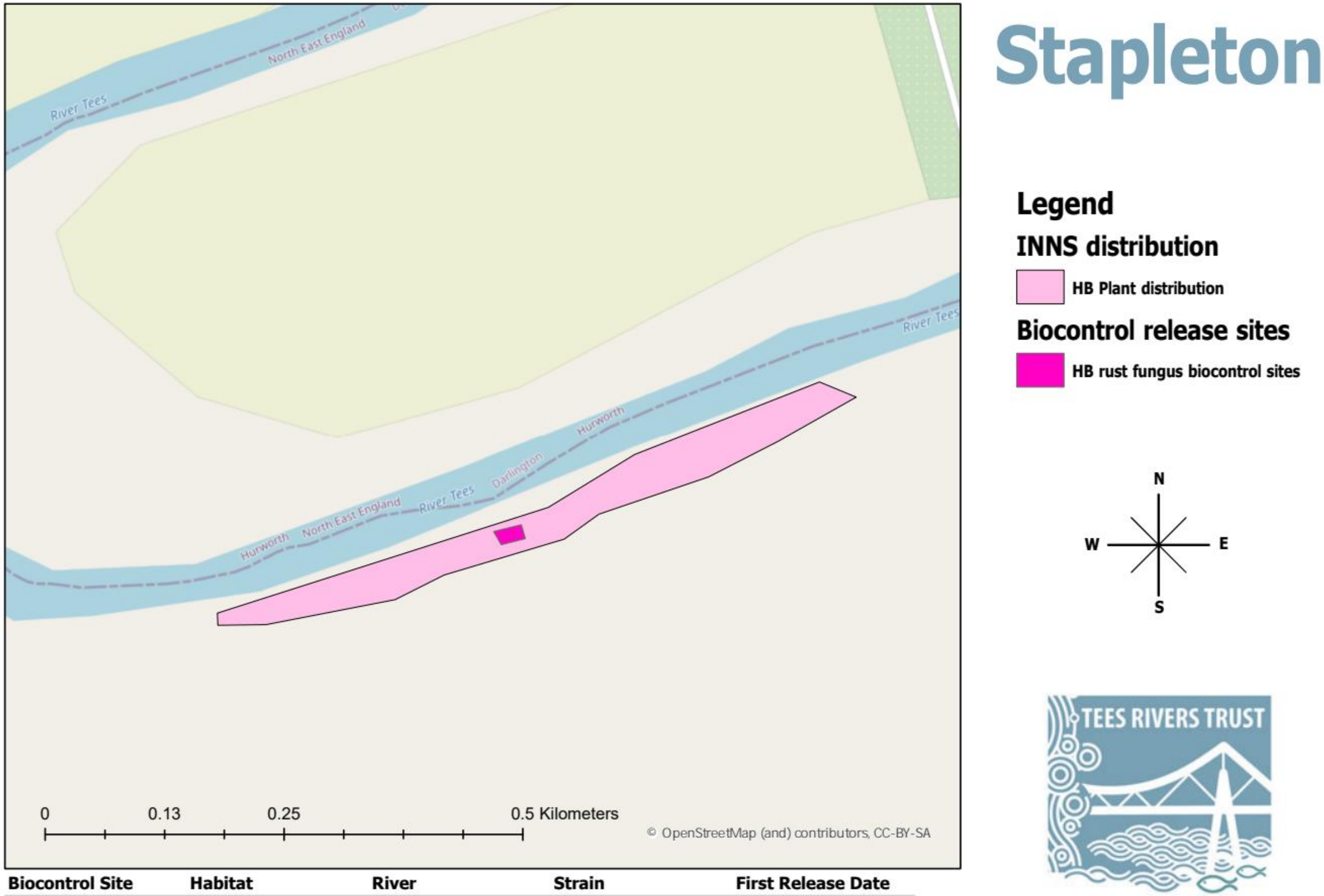
Biocontrol Site	Habitat	River	Strain	First Release Date
Hartlepool 1	Grassland	Hart Reservoir Beck	Pakistan	29.06.21
Hartlepool 2	Grassland	Hart Reservoir Beck	Pakistan	29.06.21

Figure x. Map of initial Himalayan balsam rust fungus biocontrol sites Hartlepool 1 and 2, with accompanying table of rust fungus inoculation dates for each site and strain of rust fungus applied.



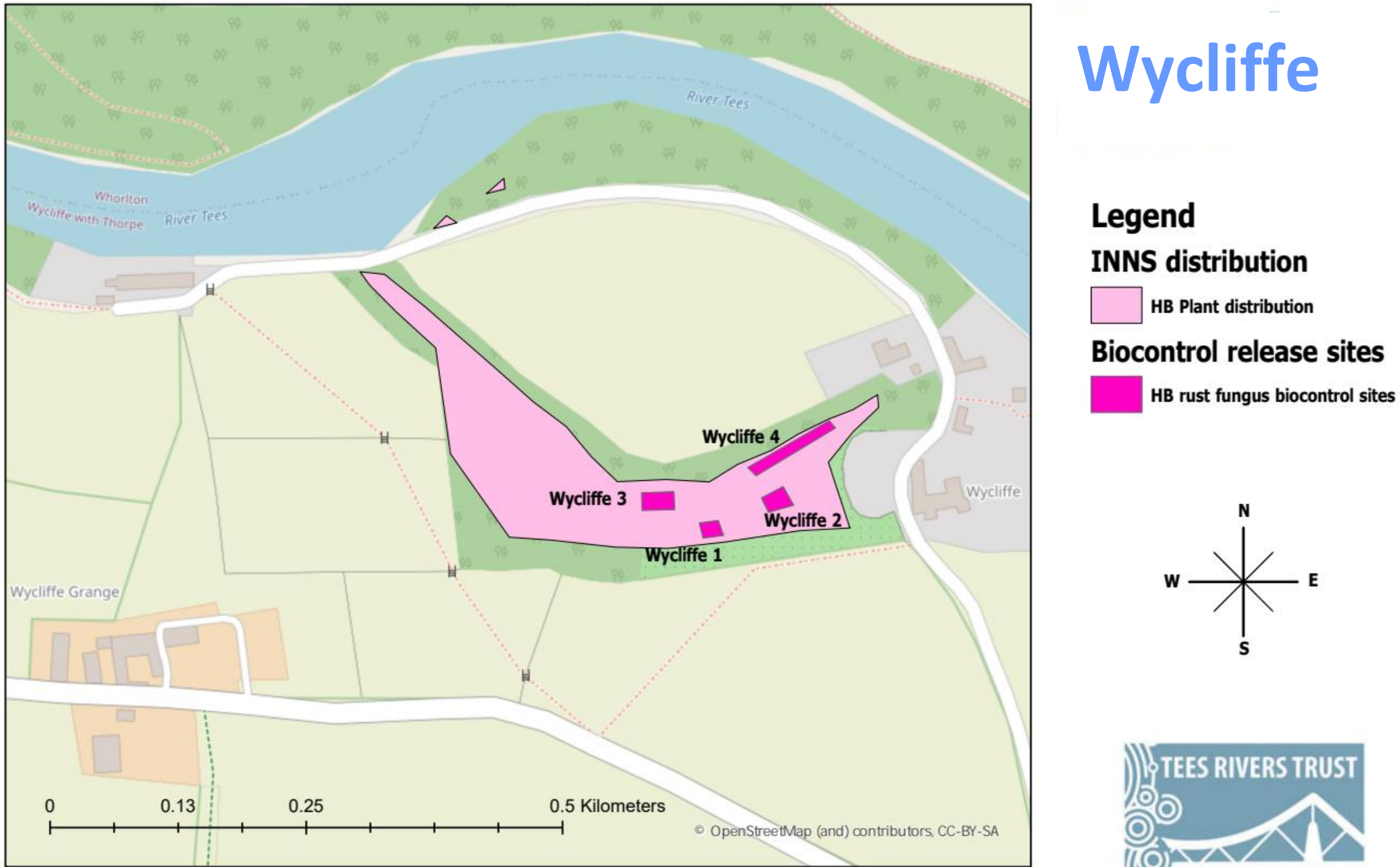
Biocontrol Site	Habitat	River	Strain	First Release Date
Ingleby Barwick 1	River Bank	River Leven	Mixed	29.06.21
Ingleby Barwick 2	River Bank	River Leven	Mixed	29.06.21

Figure x. Map of initial Himalayan balsam rust fungus biocontrol sites Ingleby Barwick 1 and 2, with accompanying table of rust fungus inoculation dates for each site and strain of rust fungus applied.



Biocontrol Site	Habitat	River	Strain	First Release Date
Stapleton	Woodland	River Tees	India	28.06.21

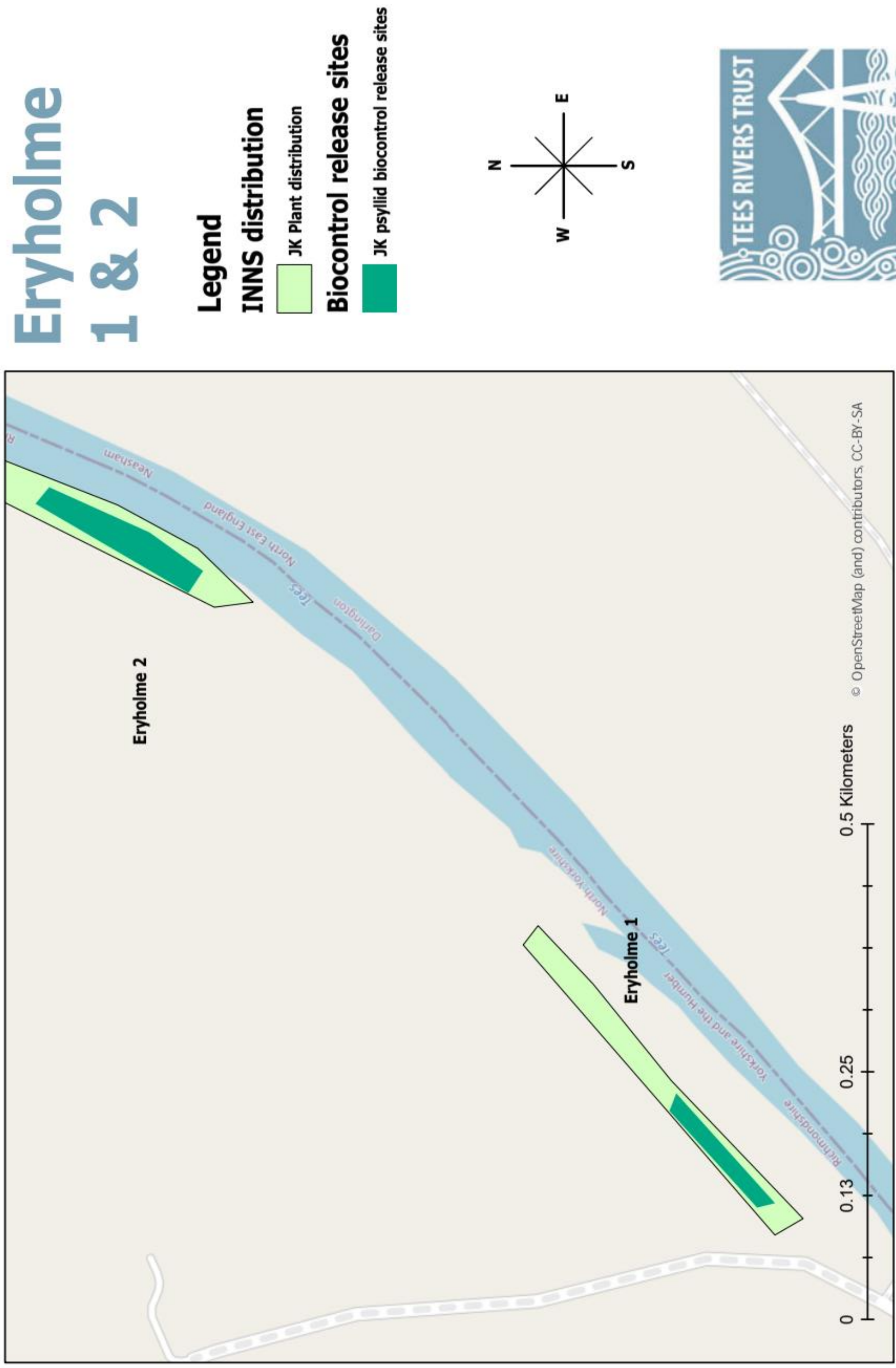
Figure x. Map of initial Himalayan balsam rust fungus biocontrol site Stapleton, with accompanying table of rust fungus inoculation dates for each site and strain of rust fungus applied.



Biocontrol Site	Habitat	River	Strain	First Release Date
Wycliffe 1	Woodland	River Tees	India	28.06.21
Wycliffe 2	Woodland	River Tees	India	28.06.21
Wycliffe 3	Woodland	River Tees	Pakistan	28.06.21
Wycliffe 4	Woodland	River Tees	Pakistan	28.06.21

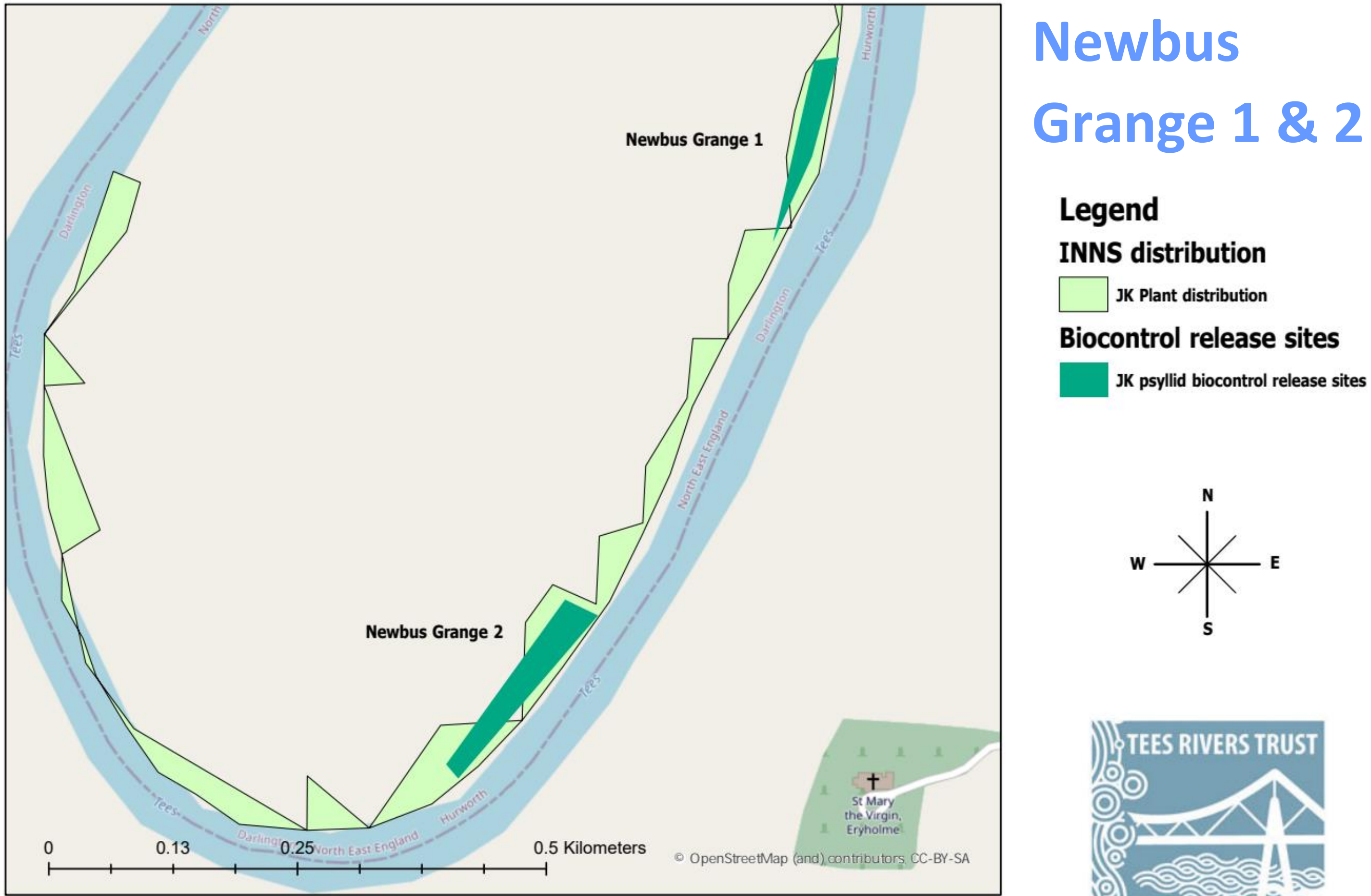
Figure x. Map of Himalayan balsam rust fungus biocontrol sites Wycliffe 1, 2, 3 and 4, with accompanying table of rust fungus inoculation dates for each site and strain of rust fungus applied.

Japanese knotweed biocontrol sites



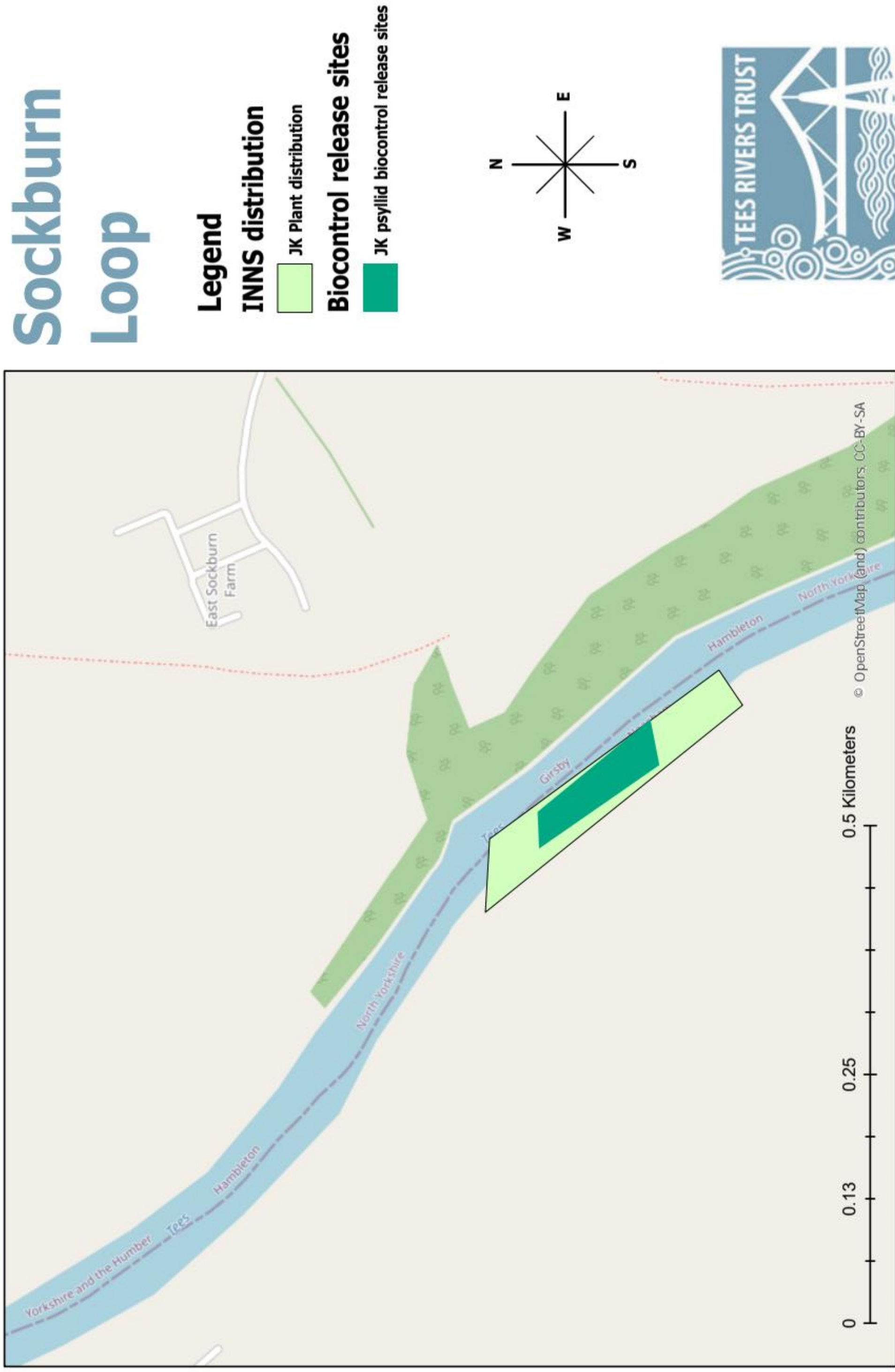
Biocontrol site	Habitat	River	First Release Date
Eryholme 1	Riparian	Tees	24/06/21
Eryholme 2	Riparian	Tees	24/06/21

Figure x. Map of Japanese knotweed psyllid biocontrol sites Eryholme 1 and 2, with accompanying table of psyllid release dates for each site.



Biocontrol site	Habitat	River	First Release Date
Newbus Grange 2	Riparian	Tees	24/06/21
Newbus Grange 1	Riparian	Tees	24/06/21

Figure x. Map of Japanese knotweed psyllid biocontrol sites Newbus Grange 1 and 2, with accompanying table of psyllid release dates for each site.



Biocontrol site	Habitat	River	First Release Date
Sockburn Loop	Riparian	Tees	24/06/21

Figure x. Map of Japanese knotweed psyllid biocontrol sites Sockburn Loop, with accompanying table of psyllid release dates for each site.

Biocontrol Progress

Himalayan Balsam Biocontrol sites

Higher resolution biocontrol progress documents have been submitted as attachments with the Completion Report.

Site Details

Site name: Barnard Castle

W3W: housework.cupboards.stay

Biocontrol Agent: Rust Fungus

Strain: Pakistan

Number of Applications: 3

Biocontrol progress

First monitoring
Date: 26.07.21

Second Monitoring
Date: 25.08.21

Third monitoring
Date: 16.09.21

Biocontrol spread

Figure x. Map of rust fungus biocontrol progress at Barnard Castle

Site Details

Site name: Cleasby

W3W: simply.thigh.fresh

Biocontrol Agent: Rust Fungus

Strain: Pakistan

Number of Applications: 2

Biocontrol progress

First monitoring
Date: 24.08.21

Second Monitoring
Date: 10.09.21

Biocontrol spread

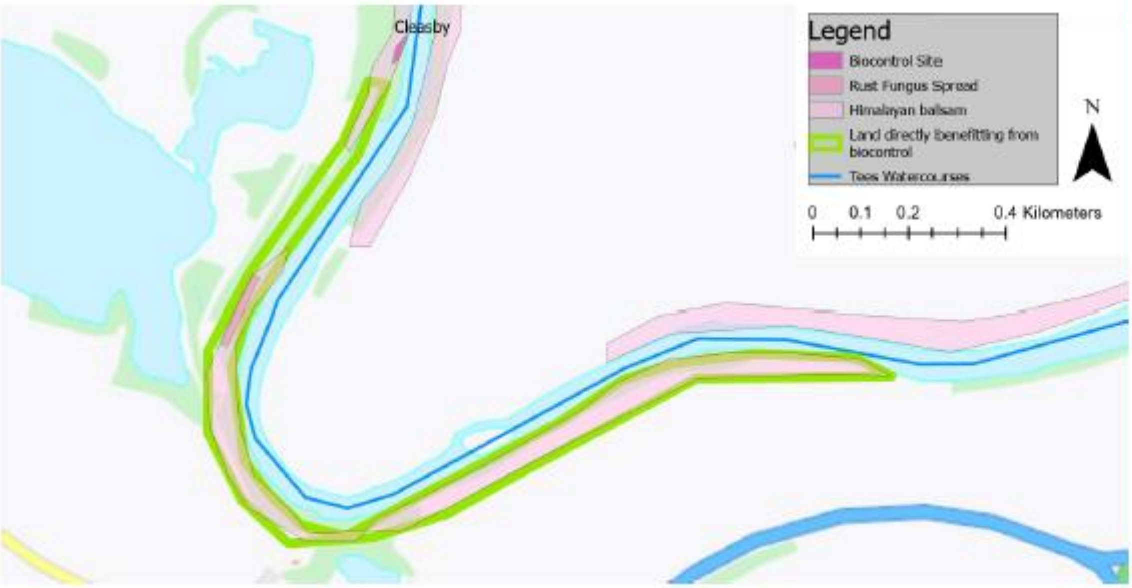


Figure x. Map of rust fungus biocontrol progress at Cleasby

Site Details

Site name: Hartlepool 1

W3W: eagles.pirate.sleeps

Biocontrol Agent: Rust Fungus

Strain: Pakistan

Number of Applications: 3

Biocontrol progress

First monitoring
Date: 27.07.21

Second Monitoring
Date: 27.08.21

Third monitoring
Date:10.09.21

Biocontrol spread

Figure x. Map of rust fungus biocontrol progress at Hartlepool 1

Site Details

Site name: Hartlepool 2

W3W: wedge.single.singer

Biocontrol Agent: Rust Fungus

Strain: Pakistan

Number of Applications: 3

Biocontrol progress

First monitoring
Date: 27.07.21

Second Monitoring
Date: 27.08.21

Third monitoring
Date:10.09.21

Biocontrol spread

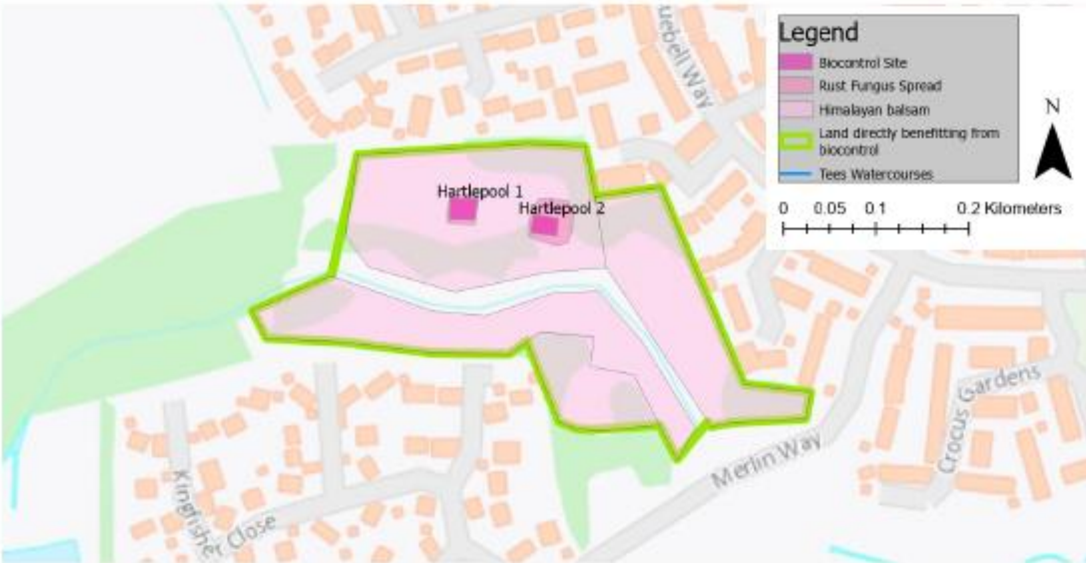


Figure x. Map of rust fungus biocontrol progress at Hartlepool 2

Site Details

Site name: Ingleby Barwick 1

W3W: slip.horn.zebra

Biocontrol Agent: Rust Fungus

Strain: Mixed

Number of Applications: 3

Biocontrol progress

First monitoring
Date: 27.07.21

Second Monitoring
Date: 24.08.21

Third monitoring
Date:10.09.21

Biocontrol spread

Figure x. Map of rust fungus biocontrol progress at Ingleby Barwick 1

Site Details

Site name: Ingleby Barwick 2

W3W: swings.chefs.festivity

Biocontrol Agent: Rust Fungus

Strain: Mixed

Number of Applications: 3

Biocontrol progress

First monitoring
Date: 27.07.21

Second Monitoring
Date: 24.08.21

Third monitoring
Date:10.09.21

Biocontrol spread

Figure x. Map of rust fungus biocontrol progress at Ingleby Barwick 2

Site Details

Site name: Stapleton

W3W: expect.become.point

Biocontrol Agent: Rust Fungus

Strain: India

Number of Applications: 3

Biocontrol progress

First monitoring
Date: 26.07.21

Second Monitoring
Date: 24.08.21

Third monitoring
Date: 17.09.21

Biocontrol spread

Figure x. Map of rust fungus biocontrol progress at Stapleton

Site Details

Site name: Wycliffe 1

W3W: wacky.hinders.unsettled

Biocontrol Agent: Rust Fungus

Strain: India

Number of Applications: 3

Biocontrol progress

First monitoring
Date: 26.07.21

Second Monitoring
Date: 25.08.21

Third monitoring
Date:10.09.21

Biocontrol spread

Figure x. Map of rust fungus biocontrol progress at Wycliffe 1

Site Details

Site name: Wycliffe 2

W3W: womanly.plankton.muted

Biocontrol Agent: Rust Fungus

Strain: India

Number of Applications: 3

Biocontrol progress

First monitoring
Date: 26.07.21

Second Monitoring
Date: 25.08.21

Third monitoring
Date:10.09.21

Biocontrol spread

Figure x. Map of rust fungus biocontrol progress at Wycliffe 2

Site Details

Site name: Wycliffe 3

W3W: finishing.orbited.down

Biocontrol Agent: Rust Fungus

Strain: Pakistan

Number of Applications: 3

Biocontrol progress

First monitoring
Date: 26.07.21

Second Monitoring
Date: 25.08.21

Third monitoring
Date:10.09.21

Biocontrol spread

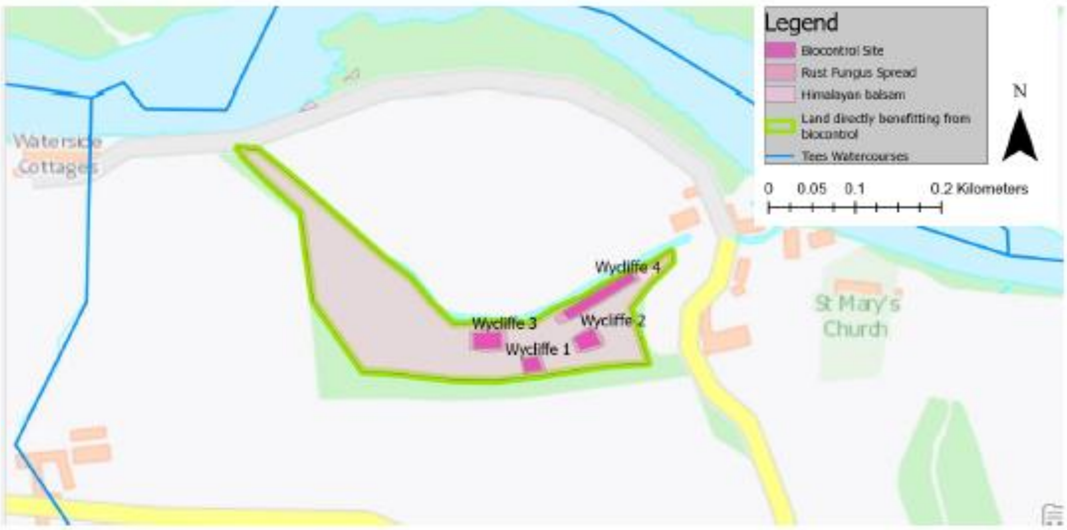


Figure x. Map of rust fungus biocontrol progress at Wycliffe 3

Site Details

Site name: Wycliffe 4

W3W: state.muddy.rekindle

Biocontrol Agent: Rust Fungus

Strain: Pakistan

Number of Applications: 3

Biocontrol progress

First monitoring
Date: 26.07.21

Second Monitoring
Date: 25.08.21

Third monitoring
Date:10.09.21

Biocontrol spread

Figure x. Map of rust fungus biocontrol progress at Wycliffe 4

Site Details

Site name: Eryholme 1

W3W: whistling.satin.woods

Biocontrol Agent: Psyllid

Strain: Mount Aso

Number of Applications: 2

Biocontrol progress

Biocontrol spread

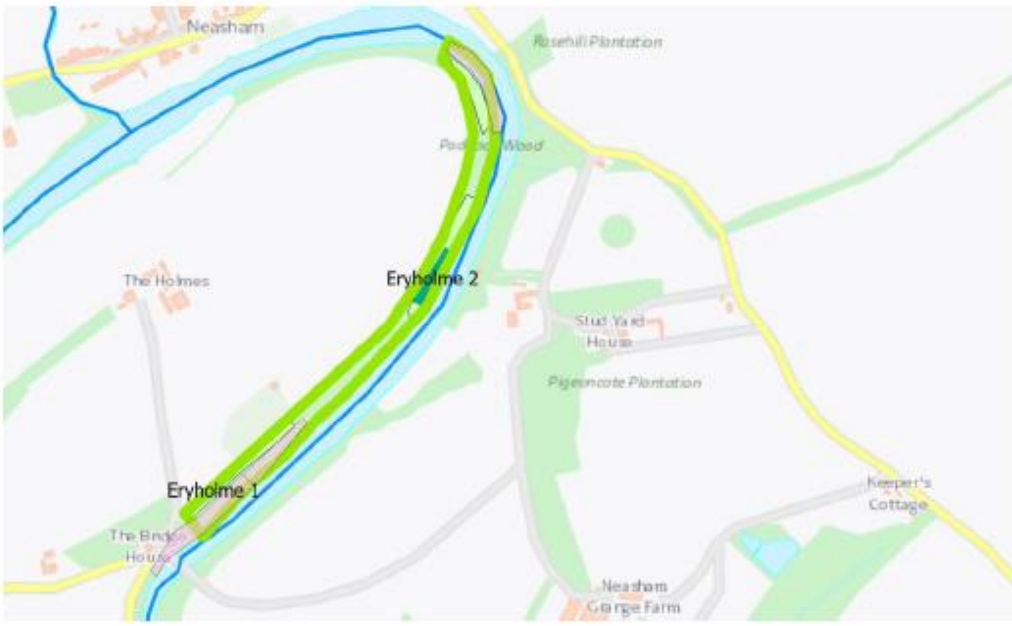


Figure x. Map of psyllid biocontrol progress at Eryholme 1

Site Details

Site name: Eryholme 2

W3W: cards.invoices.flattery

Biocontrol Agent: Psyllid

Strain: Mount Aso

Number of Applications: 2

Biocontrol progress

Biocontrol spread

Figure x. Map of psyllid biocontrol progress at Eryholme 2

Site Details

Site name: Newbus Grange 1

W3W: sharpened.toothpick.into

Biocontrol Agent: Psyllid

Strain: Mount Aso

Number of Applications: 2

Biocontrol progress

Biocontrol spread

Figure x. Map of psyllid biocontrol progress at Newbus Grange 1

Site Details

Site name: Newbus Grange 2

W3W: invested.embedded.nanny

Biocontrol Agent: Psyllid

Strain: Mount Aso

Number of Applications: 2

Biocontrol progress

Biocontrol spread

Figure x. Map of psyllid biocontrol progress at Newbus Grange 2

Site Details

Site name: Sockburn

W3W: triangles.cackling.pave

Biocontrol Agent: Psyllid

Strain: Mount Aso

Number of Applications: 2

Biocontrol progress

Biocontrol spread

Figure x. Map of psyllid biocontrol progress at Sockburn Loop

Questionnaire transcripts

Community Questionnaire

Tees Rivers Trust Biological Control Project (BINNS): Community Questionnaire
This survey has been created to gather feedback to evaluate the success and outcomes of work conducted during Tees Rivers Trust's Long-term Biological Control of Invasive Non-Native Species project. Feedback will be collated for an evaluation report that will be submitted to the funders at the end of the project (March 2022). This project was funded by the DEFRA and National Lottery Heritage Fund Green Recovery Challenge Fund.

This survey is anonymous. Personal information recorded here will be used only to share with the project funders. It will not be used for other purposes, including marketing, profiling, analysis or other purposes unrelated to the evaluation of this project.
What is your gender?

- Male
- Female
- Non-binary
- Prefer not to say
- Other

What is your age group?

- Under 16
- 16 – 19
- 20 – 29
- 30 – 39
- 40- 49
- 50-59
- 60-69
- 70-79
- 80+
- Prefer not to say

What is your ethnicity?

- Asian (Bangladeshi, Indian, Pakistani, other)
- Black (Caribbean, African, other)
- White (British, Irish)
- Mixed Ethnicity
- Prefer not to say

4. Which part of the catchment area do you live closest to?

- Darlington
- Stockton-On-Tees
- Hartlepool
- Barnard Castle

○
[ ]

Do you currently volunteer with us, or have volunteered with us in the past?

- ○ Currently volunteer
- ○ Have volunteered in the past
- ○ No

Had you heard about Japanese knotweed and/or Himalayan balsam before this project began (March 2021)?

- ○ Himalayan balsam
- ○ Japanese knotweed
- ○ Both
- ○ No

Have you gained a better understanding of the negative impact of invasive species through this project?

- ○ Strongly Agree
- ○ Agree
- ○ Neutral
- ○ Disagree
- ○ Strongly Disagree

Do you think the project has changed the way people think or feel about Japanese knotweed and Himalayan balsam, or the natural environment in general?

- ○ Yes
- ○ No

Had you heard of biological control as a method to control invasive species before this project (March 2021)

- ○ Yes
- ○ No

Do you have a better understanding of Japanese knotweed and Himalayan balsam biocontrol through our project work and community engagement (e.g. social media posts, press releases, presentations)?

- ○ Strongly Agree
- ○ Agree
- ○ Neutral
- ○ Disagree
- ○ Strongly Disagree

Please provide any other comments you have on the Tees Rivers Trust biocontrol project.

Landowner Questionnaire

Tees Rivers Trust Biological Control Project: Landowner Questionnaire

This survey has been created to gather feedback to evaluate the success and outcomes of work conducted during Tees Rivers Trust's Long-term Biological Control of Invasive Non-Native Species project. Feedback will be collated for an evaluation report that will be submitted to the funders at the end of the project (March 2022). This project was funded by the DEFRA and National Lottery Heritage Fund Green Recovery Challenge Fund.

This survey is anonymous. Personal information recorded here will be used only to share with the project funders. It will not be used for other purposes, including marketing, profiling, analysis or other purposes unrelated to the evaluation of this project.

Section 1

Which part of the Tees catchment area do you live (or own land used for the biological control project?) – please select the option closest to your area.

- ○ Darlington
- ○ Stockton-On-Tees
- ○ Hartlepool
- ○ Barnard Castle
- ○ Other

2. Which invasive species did Tees Rivers Trust begin biological control for on your land?

- ○ Himalayan balsam
- ○ Japanese knotweed
- ○ Both

3. Were you aware of using biological control as a method to control invasive species prior to this project?

- ○ Yes
- ○ No

4. Have you found the early stages of the biological control work carried out by Tees Rivers Trust beneficial so far?

- ○ Agree
- ○ Strongly Agree
- ○ Neutral
- ○ Disagree
- ○ Strongly Disagree
- ○ Do not know

5. Would you consider using biological control agents to manage invasive species on your land in the future?

- ☐ Yes
- ☐ No

6. Would you work with Tees Rivers Trust again in the future, for invasive species work or any other

work?

- ◯ Yes
- ◯ No

7. Do you have any other comments you wish to add regarding the Tees Rivers Trust's biocontrol project?