TEES RIVERS TRUST

Using a rust fungus biocontrol agent as a method of controlling Himalayan balsam *(Impatiens glandulifera)* in Great Britain

BIOCONTROL HANDBOOK:
HIMALAYAN BALSAM *(Impatiens glandulifera)*

Chloe Lawrence

2nd Edition

Organisation

Tees Rivers Trust is a charitable organisation committed to improving and conserving the River Tees and its tributaries. We take a whole catchment approach to river management, from Cross Fell to the North Sea. Our key areas of work are farm advice, invasive non-native species control, research, education, and practical habitat improvements. We are the host organisation for the Tees Catchment Partnership. This comprises partners including Local Authorities, Government Agencies, Environmental NGOs, and individual specialists. The Partnership aims to ensure catchment matters, planning and projects have a strategic and influential fit with other landscape and urban planning objectives to realise mutual benefits and avoid resource duplication. The trust is supported by a group of core trained volunteers, as well as support from regular corporate volunteers from local businesses.

Authors

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2nd Edition*

**The contents of this best practice handbook are based off Tees Rivers Trust's experience of the rust fungus biocontrol of Himalayan balsam from 2020-2022. As research and experience progresses, the methods and outcomes may vary.*

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Management Summary

Himalayan Balsam

Himalayan balsam (*Impatiens glandulifera*) is an annual weed introduced into Great Britain, mainland Europe and North America from its native range, the Western Himalayas (India and Pakistan). Himalayan balsam was introduced into Great Britain in 1839 and is now the most commonly occurring non-native plant species on riparian systems, occupying over 13% of rivers in England and Wales (CABI). This plant has detrimentally impacted the environment and economy within the Tees catchment for decades, with similar issues mirrored throughout Great Britain. Natural predators for these invasive non-native plants are not present in Great Britain, consequently enabling the plant 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.

As Himalayan balsam grows, it creates large monocultures. As the plant dies back in the winter, it leaves the ground bare and more susceptible to erosion. There are several negative effects of soil erosion additional to loss of soil fertility. This also causes increased pollution and sedimentations in the rivers, congesting waterways which causes declines in fish populations, invertebrates and the animals that feed on them. Eroded land is also less stable, meaning the impacts of climate change can worsen flooding. This also has a negative socio-economic impact on those who recreationally use the riverbanks, such as anglers, the risk of accidents increases as bank stability is worsened.

Rust Fungus Biocontrol

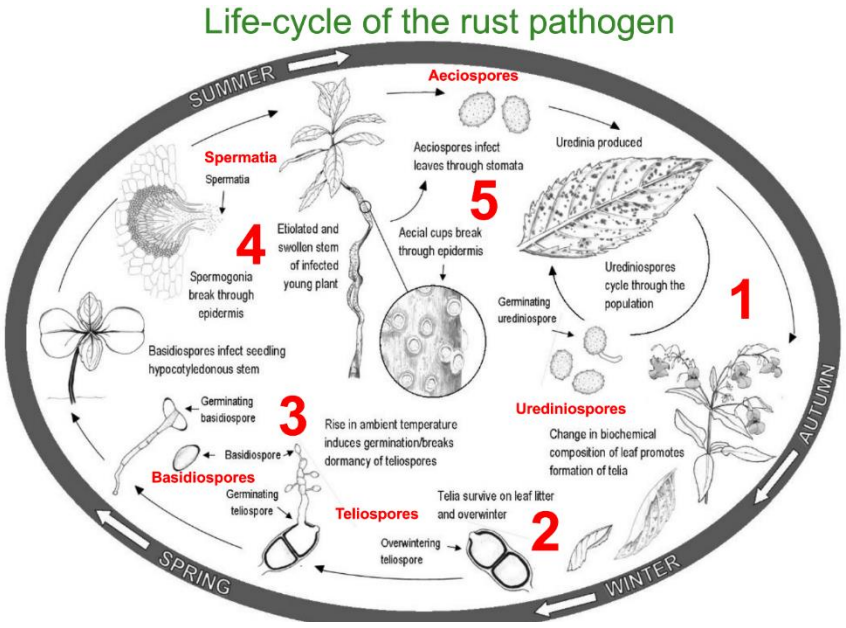
Biological control is a method of controlling pest species, particularly invasive non-native species.

The Centre for Agriculture and Bioscience International (CABI) has worked since 2006 to find a method to control Himalayan balsam. The biological control of Himalayan balsam involved finding a natural predator in its native range of the Western Himalayas to use as a biocontrol agent to control its spread in its non-native range, such as Great Britain. This required extensive testing to ensure the biocontrol agent would not negatively affect any other species in Great Britain (CABI). The rust fungus was tested in quarantine on around 70 different species and was found to be Himalayan balsam specific. The rust fungus completes its lifecycle solely on Himalayan balsam plants and does not have an impact on our native species. Tees Rivers Trust were the Northern Contractor for CABI during the field trial process.

The rust fungus has a complicated 5 stage life cycle. During the spring months it is placed on the undersides of the leaves, spreading throughout stands of Himalayan balsam. As the balsam dies back in the winter, the rust fungus goes into 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. giving native species a chance to grow. Ideally, this is a long-term solution to reduce the impact of Himalayan balsam on riverbanks.

Overall, this management method 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.



Himalayan balsam has been introduced multiple times to the UK. It is unknown how many times the plant has been introduced; however, there has been speculation that there have been at least 3 separate introductions. At present, CABI have currently found two rust fungus strains: one strain from India, and another strain from Pakistan. It is also possible there is another rust fungus strain from Cashmere still to be confirmed. Due to these multiple introductions of Himalayan balsam, Himalayan balsam plants in the UK require susceptibility testing to confirm which strain of the rust fungus will be effective in controlling the population of Himalayan balsam. There is no visual way to tell the difference between the different strains of Himalayan balsam as they all vary in height, colour, and density.

Alternative Methods

Below is a short summary of removal methods for Himalayan balsam:

Method	Pros	Cons
Manual hand pulling	Most effective for isolated populations. Good for community engagement/involvement Minimal equipment needed e.g. gloves	Time consuming Labour Intensive Not suitable for large areas
Herbicide spraying	Able to cover large areas Quicker than manual hand pulling	May damage non-target plant species Qualification and equipment needed may be costly
Cutting or mowing	Can cover large areas Quick to do	Not suitable for small patches May negatively affect non-target species
Biological control	Long term method of control Sustainable	Expensive compared to other methods Some balsam strands are not susceptible to the rust Can take years to fully establish

Biosecurity

Biosecurity involves precautions that can prevent the spread and introduction of harmful organisms. There are a few ways in which you can prevent unnecessary spread when doing the biological control work on Himalayan balsam. As Himalayan balsam spreads via seeds, and the seed pods can spread up to 7m, it is crucial to use the Check, Clean and Dry method.

Check: check your clothing and equipment for any Himalayan balsam seeds

Clean: clean all equipment, footwear, and clothing thoroughly

Dry: all equipment and clothing - some species can live for many days in moist conditions.

It is important to also be aware of any other invasive species which may be on site with Himalayan balsam such as Japanese knotweed, giant hogweed, and signal crayfish, to avoid spreading these species further.

For more information on how to reduce the spread of invasive non-native species, through good biosecurity practice, check out the Great Britain Non-Native Species Secretariat (GB NNSS) website.

Costs

The main cost of the biocontrol method is production of the rust fungus by CABI, totalling £8,000 per site. A breakdown of cost at the time of writing is provided below*
*This includes VAT and may be subject to change due to inflation.

Activity	Cost per site
Rust isolate selection • Stratification of seed (collected by collaborators the previous year) and propagation of young Himalayan balsam plants in a temperature-controlled glasshouse. • Assessment of the susceptibility of plants from each site to the two rust isolates. Two spore stages, basidiospores and urediniospores, targeting seedling hypocotyl and leaf stage, respectively. This is done by inoculating a minimum of 10 seedlings for basidiospore inoculations, and a minimum of six plants for urediniospores inoculations (if necessary – i.e., when a positive basidiospore infection in observed). • All plants monitoring closely for symptom development	£2,500
Rust production • Production of sufficient rust inoculum for three field releases in June, July, and August. • Supply of 'top-up' inoculum for the following year. • Rust is produced by infecting living plants in a temperature-controlled glasshouse. • Harvested spores are stored in liquid nitrogen to preserve viability.	£4,000
Rust release • Provision of training on releasing the rust to collaborators. • Travel and subsistence for visit to sites by CABI staff. • Supply of equipment for rust releases including: - PPE (gloves, facemask, goggles) - Data logger (for monitoring temperature and humidity) - Spray bottle - 4 vials of rust spores - 4 vials of surfactant to include in water + rust spores in spray bottle - A full instruction leaflet on the application and monitoring of the rust • Monitoring for seedling infection in spring following release, at all sites • Advice by phone and email at any time	£1,500
Total	£8,000

This does not cover cost of undertaking the rust fungus inoculations themselves, and the following expenses should also be considered:

- Staff time for
  - Seed collection in autumn prior to control site creation
  - Seeking landowner permissions
  - Rust fungus inoculation in June, July, and August
  - Rust fungus monitoring in July, August, and September
  - Overwintering monitoring the following spring
- Mileage for staff to get to the location of the site
- Equipment to set up the biocontrol site
  - Canes and coloured tape/paint to mark the site (this is dependent on location – see site marking section below).
- Bottles of water for each rust fungus inoculation
- PPE

Methods

Funding

Funding options are dependent on the number of sites created. Smaller grants are available for singular sites which would ideally need around £15,000 to cover the biocontrol and staff time to undertake the work.
It is also important to discuss plans to create biocontrol sites with CABI well in advance of submitting funding bids or planning project budgets. CABI has limited annual capacity for biocontrol agent production, so confirmation from CABI should be sought in advance of prospective biocontrol projects to avoid disappointment.

Our funding was through the Green Recovery Challenge Fund (National Lottery Heritage Fund). This covered the cost of 11 Himalayan balsam biocontrol sites, 5 Japanese knotweed biocontrol release site and a full-time project officer and part time project coordinator to cover the releases and monitoring for one year. The total cost of this project was £179,000.

Project Timescale

There is normally around a 5-week gap in between rust fungus applications. To apply the rust it normally takes around 20 minutes for the preparation making up the bottles and then actually spraying on the Himalayan balsam stands. After the second set of applications, monitoring is needed. This is a longer process and normally takes around 40 minutes. We would recommend allowing an hour for both the releases and monitoring, especially until getting used to the process.

Timescale:

Year	Month	Activity
Year 1	August	Site Selection and seeking landowner permissions
	September	Site Selection and Seed Collection
	October	Seed Drying
	November	Send Seeds to CABI
	December	
Year 2	January	CABI - Seed Rearing
	February	CABI - Seed Rearing and Testing
	March	
	April	
	May	Site set up
	June	Training with CABI - 1st Release
	July	2nd Release and Monitoring
	August	3rd Release and Monitoring
	September	Final Monitoring
	**Rust is in overwintering stage in the leaf litter as balsam dies back*	
Year 3	May	Monitoring taken place with CABI to see infection on new plants
	July	1 top up rust fungus release if needed
	August	Monitoring

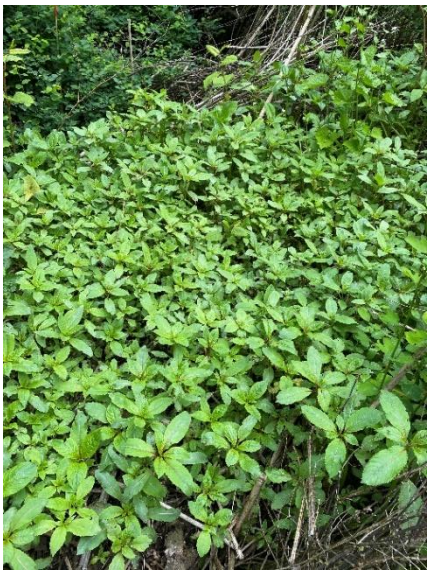
Securing Landowner Permissions

This is one of the most important aspects of the biocontrol work. As this is a long-term method to control Himalayan balsam, site selection is crucial. It is also important to have supportive landowners who are understanding of the progression and establishment of the rust fungus, and that it can take years to fully establish. This can be difficult to predict as circumstances change. However, as the rust fungus needs to be undisturbed, it is best if you are working with a landowner who will retain long-term ownership of the land where the site has been created.

It is recommended to gain written confirmation between yourselves and the landowner regarding site access, the planned work and creation of the biocontrol site, and any management of Himalayan balsam conducted by the landowner.
See example document below. (Example of landowner permission document)

Site Selection Criteria and Site Set Up

Due to the biotypic variation in Himalayan balsam, it is essential that seeds are collected, in the autumn from the exact site where the rust is to be released the following spring.



There are a few criteria for the best place to select a location for a rust fungus biocontrol site. The sites we chose covered a variety of habitats but had some features in common that made it more likely that rust fungus infection would occur. Firstly, the population of Himalayan balsam plants must be large and dense, covering a minimum area of a 10x10m2. A Himalayan balsam stand covering an area small than this reduces the chance of rust fungus spread/less as there are fewer plants to infect. The larger the area, the more chance of success.

The Himalayan balsam stands also need to be in open areas and not heavily shaded. The rust fungus is less successful in heavily shaded areas, so anywhere that receives a fair amount of sunlight would be ideal. Several our sites are within woodland areas but are still viable sites as they receive sunlight across the day.

The rust fungus also performs better in humid habitats, as humid conditions more closely reflect conditions in the native range. From our experience, rust fungus biocontrol sites located in riparian habitats tend to be more successful than in less humid locations, and this has been supported by CABI. All our current sites are either on riverbanks or within proximity to a watercourse. However, the sites should be in a stable location to ensure as minimal a chance of being washed away by flooding (CABI).

It is important to select a variety of potential sites in case the Himalayan balsam populations are not susceptible to the two available strains of the rust fungus. For example, the Himalayan balsam plants growing in three out of eight locations initially selected for our biocontrol sites were not susceptible to either strain of the rust fungus, meaning we had to create multiple sites in the locations which were confirmed to be susceptible to the rust. Therefore, alternative sites should be selected when in the early stages in case this happens. Previously we have

had 3 sites where rust fungus trials have taken place and not been susceptible, so this is important to note.

Collecting Seeds

Himalayan balsam seeds must be collected from each specific location where you plan to create a biocontrol site the year prior to planned biocontrol applications. Seed collection should be undertaken when the balsam is 'ripe' and at the 'popping' stage. This is most easily done by placing a bag over the Himalayan balsam seed pods and shaking the bag so that the movement causes the seed pods to pop in the bag. Ideally, around 150 seeds for should be collected for each site, and seeds from each location must be kept in separate bags. This is important as the seeds will be used for susceptibility testing by CABI.

The seeds collected need to be black in colour. Once collected, the seeds. must be dried for a minimum of 10 days and then counted and sorted. Once dried, the seeds will change to a tan/brown colour. At this point, around 100 seeds should be counted, selecting the biggest seeds. Once sorted, the seeds should be packaged and labelled with location and date of seed collection and sent to CABI. CABI will then store the seeds until they are ready to rear the plants to conduct the susceptibility testing.

Marking the Site

Deciding whether to mark the biocontrol release site or not can be difficult. This is completely dependent on the location of the site. Initially, we marked our sites with 8 bamboo canes marked with coloured tape. Four canes were placed in a 5x5m square area where the rust fungus would be applied, and four more canes with different coloured tape were used to mark the 10x10m^2 area surrounding the application area to easily measure roughly how far the rust may have spread within the Himalayan balsam stands. Bamboo canes were used for several reasons: they are inexpensive, easy to find in the field, and if lost, would not cause as much damage to the environment as plastic canes.
However, we did not end up placing canes at all the sites. This was due to differences in site use at these locations. On sites where the land was private, placing the canes were not an issue and these have remained in these locations (following informing the landowners about their placement). However, on sites where the land had public access, we had a few more issues in terms of placing the canes and them getting removed. 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. For our project, we have a few sites marked with canes, and a few areas that do not have canes.

What3Words

One way in which we easily locate release 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. The location is accurate to 9m^2, so using it, it is likely that we are in the right place. In the sites where there have not been canes, we have also

looked at other ways to mark the sites such as tree placement or other distinguishable landmarks.

Health and Safety

There are a few health and safety factors to be aware of when undertaking biocontrol work. Although Himalayan balsam 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. For our specific catchment area, we have an ongoing issue with giant hogweed. The giant hogweed is present at 3 of our site locations. We therefore recommend that gloves should be worn when monitoring biocontrol sites with gloves and being cautious of the surrounding area as management of other species may be required to ensure safe access to your biocontrol site, such as spot spraying giant hogweed around sites. However, this must be conducted carefully to not affect the Himalayan balsam within the biocontrol site area.

When choosing a site, accessibility must be considered. Large stands of Himalayan balsam may be found that would be ideal for rust fungus releases, but with limited/poor/unsafe access. Selecting a site like this is unadvisable. Due to the number of times, you will need to visit the site to undertake rust fungus application monitoring, sites must be in safe environment. From our perspective working on the river, we do find there are several steep banks or areas that are not easily accessible. With Himalayan balsam affecting soil quality and increasing the risk of erosion, be aware of how close to any banks you are in case they are not as stable as they look.

Biocontrol Agent Releases and Monitoring

There are 3 stages of rust applications during the first year of creating a biocontrol site, along with 4 stages of monitoring. Applications must be 4-5 weeks apart. The first release must not be undertaken until certain criteria have been reached, and this includes: the Himalayan balsam plants need to have 3 whorls of leaves on the stem, and the temperature also needs to be higher than 10 degrees Celsius during the night when rust fungus is applied. This is important as if the temperature is lower, it can risk the rust fungus going into the overwintering stage, meaning it will not spread throughout the site over the season. Following the first release, the second release needs to be undertaken 4-5 weeks later, along with the first stage of monitoring. the third and final release will then be undertaken 4-5 weeks after the second application, along with the second stage of monitoring. A third stage of monitoring must then be conducted 4-5 weeks after the last rust fungus application. The site will then be left until the following spring when overwintering monitoring will be conducted. Depending on how the overwintering monitoring in the following spring goes, there is the potential for a booster rust fungus application to improve infection success rate.

There are 2 ways which monitoring can be conducted, the first way is manually following the documentation and filling out the questions asked. The second way is similar but used online through an app. *At time of writing the app was only available on android phones, please contact CABI directly for information about the monitoring.

It is important to acknowledge that the weather may affect when rust fungus applications may be conducted. The best time to undertake rust fungus applications are in the afternoon or on a cool day, ideally it is not heavily raining to reduce the chance of the rust fungus being washed away. Alongside this, rust fungus applications should not be undertaken when it is too windy. Although this can be beneficial in spreading the rust fungus spores, it may affect monitoring the natural spread of the rust fungus within the Himalayan balsam population.

Example application and monitoring timescale

If the first set of spraying the biocontrol was undertaken on 21st June, the next release 5 weeks later would be on 26th July, the final release would be on 30th August.

Rust Fungus Infection

The rust fungus can look quite varied in the way it infects Himalayan balsam leaves. The rust pustules can either be small and cover the leaf, or larger with less coverage. See photos below for examples of rust infection on various leaves. The rust tends to be raised and if touched a rusty powder comes off the leaves.

Overwintering Monitoring

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.

Tees Rivers Trust Case Study

Our Results:

At present, all 13 of our rust fungus biocontrol sites are showing successful infection, some better than others.

Barnard Castle: There are 5 sites around this location at present which seem to be the most successful in terms of infection and spread. The location of these is in the higher points of the catchment area, success could be due to more humidity.

Darlington: There are 2 biocontrol sites within this area and although these have shown success in the early stages of rust fungus establishment, they have not shown much sign of spread. There are a few surrounding stands of Himalayan balsam infected with the rust fungus that seems to have been spread via wind, but the infection on these stands is not as prominent as other sites. A further 3 biological control sites had been located in this area which were trialled and unsuccessful, they were tested for the rust fungus but unsusceptible to both strains.

Stockton: There are 2 sites here along the river Leven, which have both shown a good amount of success in spread and in infection of the rust fungus. There is a further 1 site along the lower part of the river Leven from a previous biocontrol trial which is still showing success. These specific sites were the only 2 in the project that had a 'mixed strain' which is why it is so important to collect the seeds to be tested from the exact location of where you want the biological control management work. Further along from this site had been another alternative site which was unsusceptible despite being fairly close in distance.

*Hartlepoo*l: There are 2 sites here which are showing signs of infection, but not showing signs of success for spread. These are two of the most publicly accessible sites and we have observed sections of these sites that have been walked through/trampled on. There are canes around this site which have not been moved, but some of the Himalayan balsam plants have been crushed.

Long-term establishment and biocontrol as a management method:

There has been a prior release of the biocontrol agent in the Tees catchment in 2019. Although 3 of the sites were unsuccessful due to being unsusceptible, there is one site which is still showing success nearly 3 years later, with the hope that this site will become fully established long term. However, the other 12 sites that we have released are still in the early stages of established and must be monitored in the next few years to measure successes/failures. Further editions of this handbook will be created to monitor and measure the success as a long-term establishment. At present, it is unclear to see the success of the biocontrol as a management method, however, if successful will save money and time. CABI suggest that it can take up to 5 years for establishment of the rust fungus on a site and this project is still in the trial stage.

Educational Partnerships:

We have had an ongoing partnership with Newcastle University over the course of this project, taking out MBiol students as well as collecting data for PhD projects, including collecting soil samples and collecting environmental data from the biocontrol sites and control sites. This has been beneficial for both the students and the Trust to gain more insight into the work we are doing, as well as for the University giving students a chance to gain some practical experience in the field. Although this is initially started as a 1-year project, we hope to continue the

partnership with Newcastle University and other universities to monitor the rust fungus biocontrol as a management method to control Himalayan balsam in the future.

Volunteers:

One future option for this project will be to train volunteers to conduct the monitoring of the biocontrol sites. By educating them on the areas, and how to look out for the rust, it means that we will have more regular updates on the success. Alongside this, being aware to look out for the rust fungus' along the river means that they are less likely to be accidentally pulled out/destroyed.

Translocation:

Once sites have become established at successful over a long period, translocation to other sites may be possible, along with the natural spread of the rust fungus infection.

Lessons Learnt:

As with most projects, not everything has been smooth sailing, and we encountered a few issues along the way. In sharing this information, we hope these issues may be prevented in future projects.

Lessons Learned (1)

A site was destroyed. 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.

Some of our sites that were closer to publicly accessible paths had been trampled in areas. This can affect the success of the rust. In future, it would be best to select sites that are away from the public, such as on private land without public rights of way nearby.

Lessons Learned (2)

Data Loggers. Our data loggers did not end up being placed at the sites until after the first biocontrol release.

In hindsight, we could have placed the loggers out prior to the release to collect baseline data to compare the data of the site before and after. The other issue we encountered was data loggers going missing, especially on more public sites where the data loggers were attached to canes.

We would suggest making sure the loggers are well hidden, especially considering that the Himalayan balsam dies back. Another suggestion would be to collect data towards the end of the season and remove data loggers from the sites to reduce any chance of data loggers been lost/taken by members of public.

Acknowledgments of stakeholder involvement and expertise

CABI

The Centre for Agriculture and Biosciences (CABI) 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. Their research and work on biocontrol agents is amazing, and helpful in supporting what we want to achieve controlling Himalayan balsam. Firstly, we would like to acknowledge those at CABI, specifically Kate Pollard, Sonal Varia and Suzy Wood for their ongoing support and expertise during this project.

National Lottery Heritage Fund and Department Environment Food Rural Affairs (DEFRA)

We would like to thank the NLHF who have financially supported us to undertake this project as part of the Green Recovery Challenge Fund. Without their funding, this project would not have been possible.

Landowners

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

Bibliography and Further Resources

CABI. 2022. *CABI: Biological Control of Himalayan Balsam*. [online] Available at: <https://www.cabi.org/projects/biological-control-of-himalayan-balsam/> [Accessed 20 January 2022].

Non-Native Species Secretariat. 2022. *Himalayan Balsam, Impatiens glandulifera - GB non-native species secretariat*. [online] Available at: <http://www.nonnativespecies.org/factsheet/factsheet.cfm?speciesId=1810> [Accessed 20 January 2022].

Nonnativespecies.org. 2022. *Check, Clean, Dry*. [online] Available at: <http://www.nonnativespecies.org/checkcleandry/> [Accessed 20 January 2022].