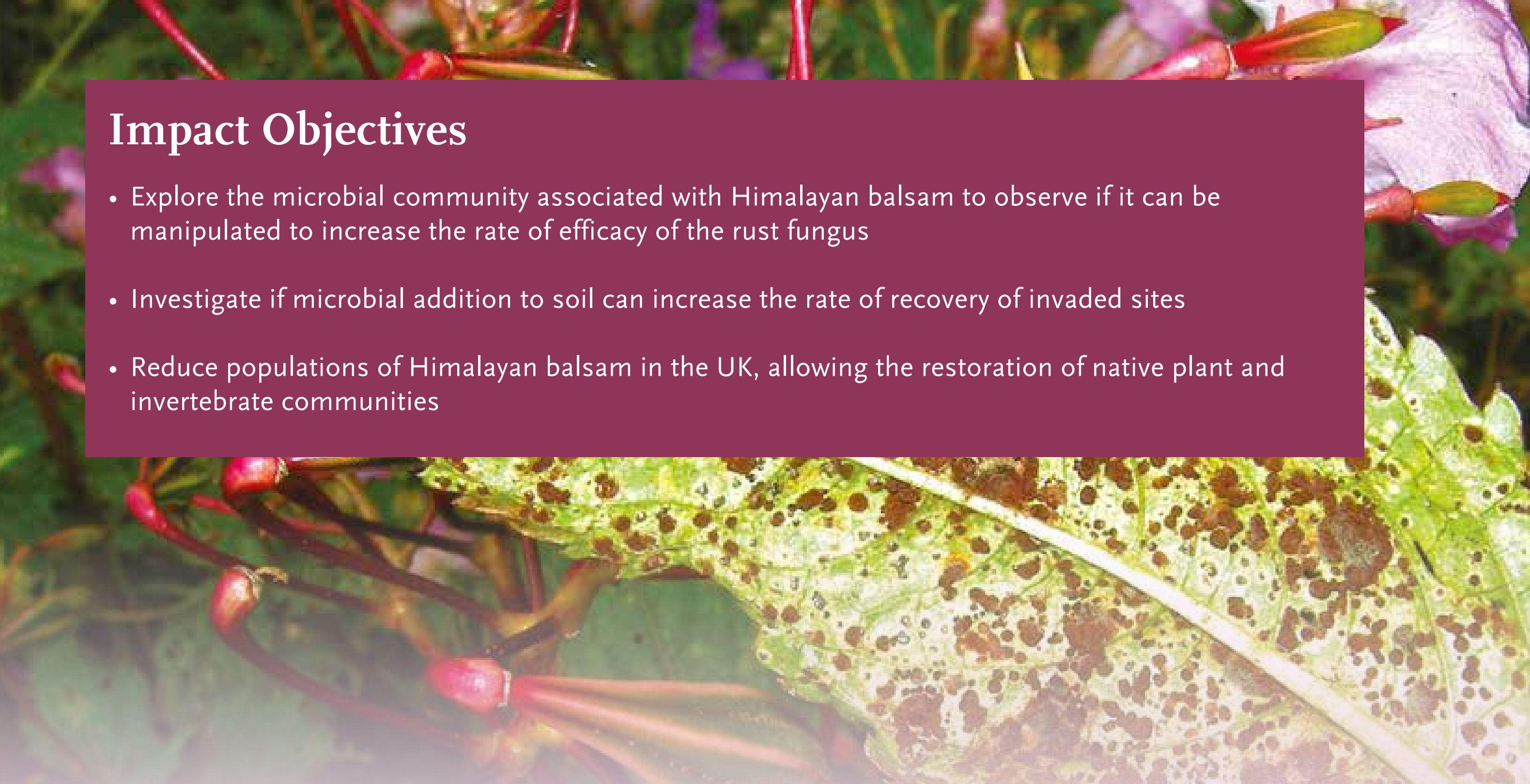
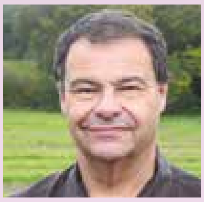


Impact Objectives

- Explore the microbial community associated with Himalayan balsam to observe if it can be manipulated to increase the rate of efficacy of the rust fungus
- Investigate if microbial addition to soil can increase the rate of recovery of invaded sites
- Reduce populations of Himalayan balsam in the UK, allowing the restoration of native plant and invertebrate communities

Pioneering biological control of alien species

***Professor Alan Gange, Professor Rob Jackson, Dr Norbert Maczey** and **Dr Carol Ellison** share their ground-breaking work utilising a rust fungus to control the invasive Himalayan balsam in the UK and the potential to replicate the approach for other invasive plant species*




Clockwise from top left: Professor Alan Gange, Professor Rob Jackson, Dr Norbert Maczey and Dr Carol Ellison

As the Principal Investigator can you share a little about what led you to research this particular topic?

AG: I completed a PhD on biological control of insect pests in orchards and then spent seven years working on insects and plant community structure at Imperial College London. I joined Royal Holloway, University of London as a lecturer in 1992 and was promoted to professor in 2007. One key moment for me was organising an international conference in 1992, when I met with mycologists and realised that I had to study fungi in plants if I was ever to understand herbivorous insect population dynamics. The second was meeting with researchers at the Centre for Agriculture and Biosciences International (CABI), where it became clear that my knowledge could be applied in weed biological control, leading to our current Natural Environment Research Council (NERC) grant on researching Himalayan balsam *(Impatiens glandulifera)*.

Could you talk a little about your latest project studying Himalayan balsam control?

AG: We are conducting experiments to see if fungi inside leaves (endophytes) and inside roots (mycorrhizas) can affect the ability of the rust fungus *(Puccinia komarovii* var. *glanduliferae)* to infect Himalayan balsam. So far, after one year, our laboratory experiments show dramatic effects of each fungal group on the other; in some instances the presence of one group can eliminate the other. In the second year of our project we will be taking these experiments out into the field, where things get a lot more complicated, but really interesting.

RJ: We are assessing the microbiome of Himalayan balsam plants that are both untreated and treated with rust fungus. Simply put, we are attempting to see if the application of the biocontrol agent starts to damage the plant such that the microbial community around the roots and inside the plant changes – and if there is change, is it a helpful or useful one (such as increasing microbes that may be detrimental to plant health or act as an indicator of plant decline).

NM: The team at CABI is covering all aspects of the project dealing with the recovery of native plant and invertebrate communities after the release of the biological control agent for Himalayan balsam. To assess this, untreated and rust treated Himalayan balsam stands in field setups and also a large scale mesocosm experiment will be compared over the course of three years. Recording of vegetation and sampling of invertebrates has been conducted at our field sites in Southern England and Wales since last year and an assessment of the first set of data is underway.

What problems and obstacles have you faced in both your lab-based and nature-based work?

AG: Germinating seeds of Himalayan balsam in the laboratory! For such a successful plant, it is remarkably difficult to germinate the seeds – they need a very long period of chilling in the fridge; a likely throwback to their original habitat in high Himalayan valleys. In the field, the most difficult thing is experimentally infecting plants with fungi, as high humidity is required – not easy in very dry springs such as 2017.

NM: There are many practical difficulties in undertaking this project. Himalayan balsam is a very variable plant: the variation in plant growth within a field site can be huge, let alone between sites! This makes comparable sampling of invertebrates a challenge. The plant loves to grow in wet habitats, which has resulted in experimental disruption due to flooding. Many biological control projects are comparably small investments and will often lead to very significant economic benefits in the long term. Despite this, securing funding to conduct the necessary research and risk assessments has become increasingly difficult.

What made the rust fungus a particularly good choice as a biological control?

CE: Rust fungi are often extremely host specific, sometimes even only infecting a limited number of genotypes of the target weed, which makes them very safe to use. The spores of rust fungi are able to spread naturally in wind currents to new hosts, often over very long distances in a few hours. There are numerous examples where rust fungi have proven to be very effective providing a sustainable long term solution for the control of individual invasive plant species.

How does one limit the downsides of introducing a new alien species?

AG: Prior to release, to perform studies that address how the 'new' species will interact with other non-target species. For example, in the last century, many insects introduced as biological control agents failed because the local predators and parasites suddenly had a banquet and the control agent was controlled!

CE: In the majority of cases appropriate host range testing and risk assessments can minimise any risks posed to non-target species completely. However, sometimes there remain some conflicts of interest, for example when the invasive species is of some value for example as an ornamental plant or by providing natural shelter for farm animals or as a source of firewood. In such cases intensive stakeholder consultations are necessary, and a cost:benefit analysis undertaken before a release of a suitable control agents can be considered.

In what ways would the potential success of the rust fungus open the door to other biological control strategies?

AG: Some endophyte fungi inside the leaves can increase the growth of their host, while others can decrease it. If we can find the 'right' combinations of fungi then control should become much more efficient and the likelihood of host resistance evolving should be minimal, as these are natural systems that we are exploiting.

NM: Success of the rust fungus would provide support for targeting other invasive species both using fungal pathogens and insect control agents, which are also used in this strategy. Sometimes the combined use of a pathogenic fungus with an insect herbivore can improve efficacy, particularly when the insect acts as a vector for the pathogen.

Could you talk a little about the collaborative nature of the project?

AG: Royal Holloway coordinates the project and conducts the observational and manipulative experiments with the endophytes, mycorrhizas and the rust fungus. Laboratory and field experiments are designed to find the 'ideal' combinations of fungi that reduce Himalayan balsam growth and reproduction. We recover our infective fungi through culturing, but then pass our samples to the University of Reading for molecular identifications of species.

CE: CABI is covering any aspects regarding the impact of the rust fungus on invertebrates. Many of the activities conducted during the projects are based on joint setup of experiments requiring an intensive collaboration between the different partners. The work also fits in well with other aspects of the rust fungus release and monitoring work primarily using public funding. Collaboration with Local Action Groups, such as Wildlife and River Trusts as well as, Local Authorities, forms part of the project enabling the establishment of release sites that are then monitored under the NERC funding.

Beyond herbicides

A collaborative team of scientists from ***Royal Holloway, University of Reading*** *and the* ***Centre for Agriculture and Biosciences International*** *are looking to enhance the effectiveness of the biological control of invasive species*

Invasive species are becoming ever more common. They often arrive in new habitats without any natural predators meaning they often have a significant advantage over native species. Invasive species can easily become dominant and cause a multitude of problems in natural habitats. This phenomenon is not limited to animals but applies to plants and even microorganisms.

Impatiens glandulifera (Himalayan balsam) is a flowering plant that is causing particular problems along the banks of UK rivers and waterways. The plant dominates many riversides, which has led to several problems, for instance it dies off in the winter and leaves the soil exposed to erosion. Despite this, the soil does not get re-colonised by native plants. Research has shown that this is due to alterations in the soil microbiota by the Himalayan balsam. Additional issues are caused by clogging of waterways by the plant and its potential to attract pollinators that other species require. Using herbicides is ineffective both due to the proximity to waterways and the alterations to the soil made by the plant. Regular removal by volunteers can be effective, but is slow and costly in terms of labour. One novel method to reduce the invasive population is the introduction of an organism that hinders the growth of the Himalayan balsam, otherwise known as a biological control agent.

> *Biological control is effective and environmentally friendly, but by enhancing its efficacy, the door will be opened for a wide variety of alien species to be controlled using this approach in the future*

BIO-CONTROLS

In the Himalayas, it is a specific species of rust fungus *(Puccinia komarovii* var. *glanduliferae)* that infects and controls the Himalayan balsam. Collaborative work by Professor Alan Gange of Royal Holloway, University of London, Professor Rob Jackson of the University of Reading, Dr Norbert Maczey and Dr Carol Ellison of the Centre for Agriculture and Biosciences International (CABI) is investigating using the rust fungus to tackle Himalayan balsam's spread in the UK. This is a three-year Natural Environment Research Council (NERC)-funded project that will be completed in November 2018.

The work is largely split between the laboratory and the field with the team monitoring the growth and microbiota of Himalayan balsam in both contexts. This involves going out into the field and collecting samples, as well as developing a method of culturing fungi infecting Himalayan balsam in a laboratory environment. These samples are then examined using molecular methods of genetic identification. 'This allows us to identify the composition of the microbiota, particularly the fungi present in the leaves (endophytes) and in the roots (mycorrhizas), both of which are essential to the plant's growth, observes Gange.

FUTURE OF THE FUNGUS

This first step of the project has been the introduction of the rust fungus into selected field sites. The fungus has been released in a few test areas and its impact is being monitored in several ways. Gange says that monitoring the rust's effectiveness in reducing balsam populations is essential, but also other impacts are being studied: 'The team are looking at the recovery of native species in place of the Himalayan balsam, the impact of changing plant populations on the soil microbiota and on the local insect populations.'

There is still plenty to be gleaned from this work and the team are excited about what the experiments will reveal. The ultimate impact of this work will likely extend further than just the control of Himalayan balsam. 'Biological control is effective and environmentally friendly, but by enhancing its efficacy, the door will be opened for a wide variety of alien species to be controlled in the future', Gange says. This would have a great impact on how we deal with invasive species and significantly aid the maintenance of important native habitats.

Project Insights

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PARTNERS
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Professor Alan Gange is a Professor of Microbial Ecology in the School of Biological Sciences, Royal Holloway, University of London. His interest lies in studying the multitrophic interactions which affect the diversity and structure of plant communities, with a focus on the interactions between organisms from more than two trophic levels, in natural, semi-natural and managed plant assemblages.