Out of sight, out of mind? *Ex-situ* germination of X *Reyllopia conollyana* (Conolly's Knotweed) in a South Wales invaded seed bank

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X *Reyllopia conollyana* seedling growing in the Swansea University glasshouse facilities in May 2019. *Sophie Hocking.*

The knotweed *Reynoutria (Fallopia) japonica* var. *japonica* (Japanese Knotweed) is the most common of four key invasive taxa found in the UK (Stace 2019). Collectively, these invasive knotweeds, including any F2s or backcrosses, are referred to as 'Japanese Knotweed' *sensu lato* after Bailey & Conolly (2000).

In the UK non-native range, *R. japonica* has achieved public notoriety owing, in large part, to irresponsible media coverage, unclear control treatment options and frequently excessive costs associated with management, particularly where it is affecting residential property transactions. However, *R. japonica* is unique within the UK flora, in being a rhizomatous perennial geophyte (according to the Raunkiaer system), and it is this rhizome-forming growth strategy which underpins the genuine challenges that this knotweed presents.

In an ecological context, *R. japonica* is a fast-growing competitor (C-strategist; Grime, 2001), growing quickly from dormant rhizome buds early in the growing season. This early, prolific growth is powered by extensive rhizome reserves accumulated in previous growing seasons. The accumulation of a thick, persistent layer of leaves and dead stems from previous growing seasons is also a characteristic feature of knotweed patches or 'stands'. Owing to this, all but a few shade- and litter-tolerant vernal species, such as *Hyacinthoides non-scripta* (Bluebell) and *Arum maculatum* (Lords-and-Ladies), and/or climbing species that are able to grow up the stems and access the canopy, such as *Calystegia sepium* (Hedge Bindweed), can persist. These stands are typified by an impoverished flora and fauna, alterations to nutrient cycling and topsoil fertility and there are 'knock on' negative effects beyond the stand on terrestrial and aquatic invertebrates communities (Beerling *et al.*, 1994; Grime, 2001; Maerz *et al.*, 2005; Vanderhoeven *et al.* 2005;

Dassonville *et al.*, 2007; Gerber *et al.*, 2008; Seeney *et al.*, 2019).

Rhizomatous growth also impacts upon the built environment, with rhizomes capable of damaging and displacing man-made structures (EA, 2013), although such impacts are currently a topic of a highly contentious debate, particularly within the knotweed remediation industry (Fennell *et al.*, 2018). Rhizomes also impinge upon management of *R. japonica*, with depletion of the rhizome system by biocontrol or physical control treatments all but impossible, certainly within decadal timescales. Complete excavation with on- or off-site disposal is possible, if undertaken correctly, but this is an order of magnitude more expensive than herbicide-based control. Only glyphosate-based herbicides are effective for above ground control of knotweed growth in the UK. However, the rhizome frequently remains alive and ongoing vigilance for more than three years is required to ensure the success of any control treatment (Jones *et al.*, 2018).

Development of first true leaf on X *Reyllopia conollyana* one week after emergence. *Sophie Hocking*

Development of X *Reyllopia conollyana* one month post-emergence. *Sophie Hocking*

Perhaps most interestingly, *R. japonica* is widely distributed throughout the UK, despite being largely restricted to asexual (clonal) dispersal through direct expansion of rhizomes and via diaspores: primarily rhizome and stem fragments, but also leaves (Brabec & Pyšek, 2000; Bailey *et al.*, 2009; Akeroyd, 2014; Jones, 2015). This remarkable spread without viable seed production is made possible by anthropogenic and natural disturbance processes (e.g. riparian flooding), hastened by poor management practices and disposal of soil contaminated with rhizomes (both deliberate and inadvertent) (Dawson & Holland, 1999; Bailey *et al.*, 2009). Consequently, all *R. japonica* plants in the UK originate from a single female clone (Bailey, 2013).

In 2018, Jones *et al.* conducted the most comprehensive field-scale, Integrated Pest Management (IPM) assessment of *R. japonica* control methods. The largest of the three field trial sites, the Invasives Research Centre, is a 5ha site in Taff's Well, near Cardiff. Building upon this investigation, our research at Swansea University Department of Biosciences aims to assess: the longer-term ecological impacts of effective *R. japonica* control; secondary invasion processes by subdominant invasive plants, such as *Impatiens glandulifera* (Indian balsam), and, uniquely in Europe, habitat restoration approaches for ecologically degraded habitats previously dominated by invasive species.

Investigating the seed bank

To investigate passive and active habitat restoration, we evaluated the regeneration potential of the native flora seed bank present at the Taffs Well site. To achieve this, a seed bank study was established in February 2019 using soil samples collected using a metal auger (soil borer) from field trial plots. These plots had been subjected to above-ground *R. japonica* treatment. All samples collected were stored safely in sealed and labelled plastic bags.

Emergence of the seedling

In the Swansea University glasshouse facility, samples were split into three replicates, spread over seedling trays and grown under glasshouse conditions. Methods for this study were developed following Wagner *et al.* (2017), with advice from Wagner (pers. comm. 2018). After three weeks, an unidentified non-native knotweed plant was observed emerging with no visible rhizome material attached and the seed

case still present on the cotyledon, i.e., the plant had germinated from seed. This seedling was transplanted and grown on for the purposes of species-level identification (see photographs for development of the seedling). When the seedling had more fully developed to allow observation of leaf and stem features critical for species-level identification, images were shared with Dr Tim Rich and Dr John Bailey, who confirmed the identity of the plant as X *Reyllopia conollyana* (J.P. Bailey) Galasso (*Fallopia* × *conollyana)* (Conolly's Knotweed) (Stace, 2019). The parentage of this intergeneric hybrid involves *Reynoutria japonica* and *Fallopia baldschuanica* (Russian-vine).

History of a hybrid

Interestingly, X *Reyllopia conollyana* was first discovered in Wales in 1983 as an open-pollinated seed from *R. japonica*, almost 100 years after the first specimens of *R. japonica* were found growing in the wild in Maesteg (Wales). Shortly after the original find of X *Reyllopia conollyana* in 1983, another was found in Middlesex (Bailey, 2001).

Although most seed produced by *R. japonica* in the UK and Europe contains X *Reyllopia conollyana* embryos, only a very small fraction have been reported to germinate and successfully grow in the wild (Bailey & Spencer, 2003, Hoste *et al*., 2017). Past viability tests have yielded good results and germination rates are high under greenhouse conditions (Bailey, 2003; Tiébré *et al*., 2007, Hoste *et al*., 2017). It is consequently thought that germination success in the UK is primarily limited by a combination of mild winters and a characteristically underdeveloped endosperm that potentially increases susceptibility to attack by soil fungi (Bailey & Spencer, 2003). Furthermore, these hybrids are slow-growing and require bare ground for colonisation (Hoste *et al*., 2017). This is also evident from observations of *Reynoutria* species in their native ranges, where recruitment by seed is favoured when there is open ground, whereas vegetative reproduction is favoured when space is occupied by other vascular plant species (Bailey & Spencer, 2003).

The seedling found in soil from Taff's Well is thought to have originated from seed rain accumulated in the previous growing season and had survived the winter in the field. However, no further individuals of X *Reyllopia conollyana* or *Fallopia baldschuanica* have been identified growing at the site. Consequently, the presence of this hybrid knotweed in the seed bank provides an interesting opportunity to further understand the invasion dynamics of these knotweeds.

Certainly, as climate change continues to alter environmental conditions, occurrence of this hybrid may become more frequent in the future (Polgar *et al*., 2014). The effects this will have on invasive knotweed control are unknown, although as Bailey (2008) notes: 'Spread of such hybrid plants and the possibility of back-crossing recreating the missing hermaphrodite *F. japonica* var. *japonica*, are outcomes best avoided'.

More immediately, increasing incidence of X *Reyllopia conollyana* may create identification issues for those involved in knotweed remediation, whereby costly management operations are misdirected at what is believed to be *R. japonica*. Another potential impact of the hybrid may be through modification of the post-treatment seed bank, altering successional processes and passive recolonisation processes.

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References

Akeroyd, J.R. 2014. *Docks and Knotweeds of Britain and Ireland* (2nd ed.). Botanical Society of Britain and Ireland, London

Bailey, J.P. & Conolly, A.P. 2000. Prize-winners to pariahs – A history of Japanese Knotweed *s.l.* (Polygonaceae) in the British Isles. *Watsonia* 23: 93–110.

Bailey, J.P. 2001. *Fallopia* × *conollyana* The Railway-yard Knotweed. *Watsonia* 23: 539–541.

Bailey, J.P. 2003. Japanese knotweed s.l. at home and abroad. pp. 183–196. In: Child, L. Brock, J.H., Prach, K., Pyšek, P., Wade, P.M., Williamson, M., (eds.) *Plant invasions – ecological threats and mangement solutions.* Backhuys Publishers, Leiden.

Bailey, J.P. 2013. The Japanese knotweed invasion as a vast unintentional hybridization experiment. *Heredity* 110: 105–110.

Bailey, J.P. & Spencer, W. 2003. New records for *Fallopia* × *conollyana*: is it truly such a rarity? *Watsonia* 24: 452–453.

Bailey, J.P., Bímová, K. & Mandak, B. 2009. Asexual spread versus sexual reproduction and evolution in Japanese Knotweed *s.l.* sets the stage for the 'Battle of the Clones'.

Biological Invasions 11: 1189–1203.
Beerling, D.J., Bailey, J.P. & Conolly, A.P. 1994. *Fallopia japonica* (Houtt.) Ronse Decraene. *The Journal of Ecology* 82(4): 959–979.
Brabec, J. & Pyšek, P. 2000. Establishment and Survival of Three Invasive Taxa of the Genus *Reynoutria* (Polygonaceae) in Mesic Mown Meadows: A Field Experimental Study. *Folia Geobotanica* 35: 27–42.
Dassonville, N., Vanderhoeven, S., Gruber, W. & Meerts, P. 2007. Invasion by *Fallopia japonica* increases topsoil mineral nutrient concentrations. *Ecoscience* 14(2): 230–240.
Dawson, F.H. & Holland, D. 1999. The distribution in bankside habitats of three invasive plants in the U.K. in relation to the development of control strategies. *Hydrobiologica* 415: 193–201.
EA, UK Environment Agency 2013. The Knotweed Code of Practice. (UK) Environment Agency (EA), pp. 10–14.
Fennell, M., Wade, W. & Bacon, K.L. 2018. Japanese knotweed *Fallopia japonica*: an analysis of capacity to cause structural damage (compared to other plants) and typical rhizome extension. *PeerJ* 6:e5246 https://doi.org/10.7717/peerj.5246
Gerber, E., Krebs, C., Murrell, C., Moretti, M., Rocklin, R. & Schaffner, U. 2008. Exotic invasive knotweeds (*Fallopia* spp.) negatively affect native plant and invertebrate assemblages in European riparian habitats. *Biological Conservation* 141(22): 646–654.
Grime, J.P. 2001. Plant Strategies, Vegetation Processes and Ecosystem Properties. John Wiley & Sons, Chichester, West Sussex.
Hoste, I., Verloove, F., Bailey, J. 2017 Two recent records from Belgium of established plants of *Fallopia* × *conollyana*: A low profile alien steps into the open. *Dumortiera* 112: 8–13.
Jones, D.L. 2015. Japanese Knotweed *s.l.* Taxa and Introduced *Petasites* Species: Biosystematics, Ecology and Control. PhD Thesis, Swansea University, Swansea.
Jones, D.L., Bruce, G., Fowler, M.S., Law-Cooper, R., Graham, I., Abel, A., Street-Perrot, A. & Eastwood, D. 2018. Optimising physiochemical control of invasive Japanese knotweed. *Biological Invasions* 20(8): 2091–2105.
Maerz, J.C., Blossey, B. & Nuzzo, V. 2005. Green Frogs Show Reduced Foraging Success in Habitats Invaded by Japanese knotweed. *Biodiversity and Conservation* 14: 2901–2911.
Polgar, C., Gallinat, A. & Primack, R.B. 2014. Drivers of leaf-out phenology and their implications for species invasions: insights from Thoreau's Concord. *New Phytologist* 202(1): 106–115.
Stace, C. 2019. *New Flora of the British Isles* (4th ed.). Cambridge University Press, Cambridge.
Seeney, A., Pattison, Z., Willby, N. J., Boon, P.J. & Bull, C.D. 2019. Stream invertebrate diversity reduces with invasion of river banks by non-native plants. *Freshwater Biology* 64: 485–496.
Tiébré, M.S., Vanderhoeven, S., Saad, L. & Mahy, G. 2007. Hybridization and Sexual Reproduction in the Invasive Alien *Fallopia* (Polygonaceae) Complex in Belgium. *Annals of Botany* 99: 193–203.
Vanderhoeven, S., Dassonville, N. & Meerts, P. 2005. Increased topsoil mineral nutrient concentrations under exotic invasive plants in Belgium. *Plant & Soil* 275(1–2): 169–179.
Wagner, M., Walker, K.J. & Plywell, R.F. 2017. Seed bank dynamics in restored grassland following the sowing and high- and low-diversity seed mixtures. *Restoration Ecology* 25: 1–11.

Reynoutria japonica. Paul Sterry

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