Research
Based
Curricula

Japanese Knotweed: The Misunderstood Menace

Key Stage 5 Biochemistry

Resource 1

2019

Resource One Overview

Topic	The Balance of Life
A-Level Modules	Populations in ecosystems

Objectives

By the end of this resource, you will be able:

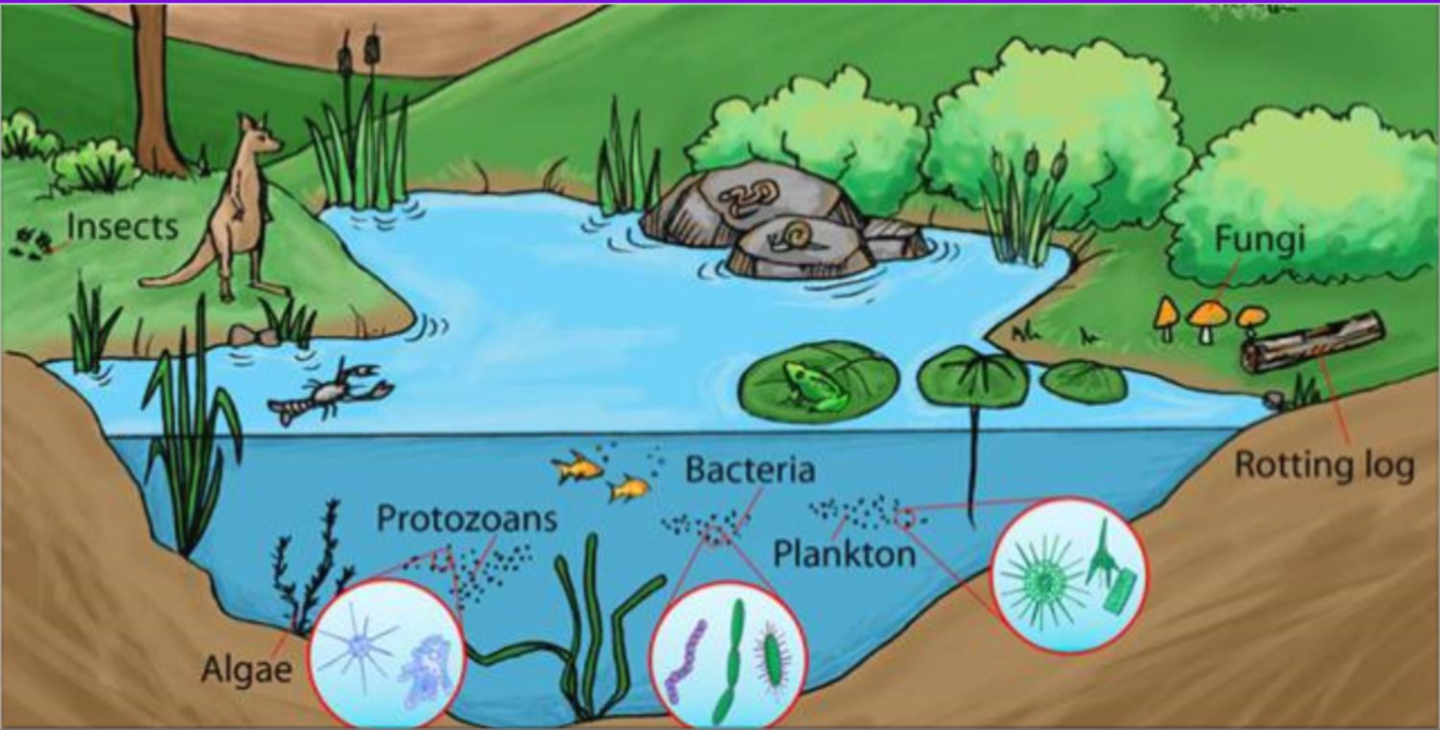
- ✓ To understand how ecosystems are a fine balance, and how populations interact
- ✓ To understand the process of succession
- ✓ To understand how Japanese knotweed can play a part in succession
- ✓ To understand the concept of biodiversity

Instructions

1. Read the data source
2. Complete the activities
3. Explore the further reading

Context

Ecosystems and the niche occupied by different species. Competition between different populations. How changes in abiotic conditions can lead to succession. Methods to estimate the size of populations.



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Data Source

Section A

What is an ecosystem?

An ecosystem is a biological community of interacting organisms and their physical environment. Like all things in biology, ecosystems are finely balanced, and changing one part will have an impact on the rest. An ecosystem is a dynamic system. Populations of different species form a community. A community and the non-living components of its environment together form an ecosystem. Ecosystems can range in size from the very small to the very large. Within a habitat, a species occupies a niche governed by adaptation to both abiotic and biotic conditions.

Section B

Adaptation and niches

The plant species which I study, Japanese knotweed, is native to Asia. Here it finds its niche as the first plant to colonise volcanoes after volcanic eruptions. Despite fertile soil, volcanic landscapes also present difficulties due to steep slopes, acidity, and the release of sulphur dioxide. In volcanic soil, the levels of available phosphorus, a vital nutrient to plants, can be low due to the reaction of soluble phosphorus to form solid compounds of low solubility.

If the phosphorus is not soluble then it is not available in the soil water and cannot easily be taken up by plant roots. Japanese knotweed has several adaptations which allow it to overcome these difficulties. Japanese knotweed has a high tolerance of sulphur dioxide and can grow across a range of pHs. It has a large underground storage organ system called a rhizome. The system of rhizomes can help stabilize soil, see later section on erosion prevention. The rhizome can spread outwards underneath the soil from the initial site of growth. From this underground network bamboo-like shoots called canes sprout upwards. The patch of Japanese knotweed formed in this manner is referred to as a 'stand'. These stands are often very densely packed with lots of large leaves coming from the canes.

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Section C

Succession

Ecological succession is the name given to a process by which the structure of a biological community evolves over time. There are two types of succession, primary and secondary. Primary succession occurs in harsh areas, where the soil does not lend itself easily to the sustenance of life. Examples of such areas include recent lava flows, newly formed sand dunes, or rocks left from a retreating glacier.

Secondary succession occurs in areas where a small-scale disturbance does not eliminate all life and nutrients from the environment but does cause the removal of a community which previously existed, allowing an opening in a niche for a new species to become established.

Colonisation by pioneer species which is adapted to the harsh conditions, such as Japanese knotweed, allows for primary succession. Primary succession can transform a landscape from a barren environment to climax community. At each stage in succession, certain species may be recognised which change the environment so that it becomes more suitable for other species with different adaptations. The new species may change the environment in such a way that it becomes less suitable for the previous species. Changes that organisms produce in their abiotic environment can result in a less hostile environment and change biodiversity. Conservation of habitats frequently involves management of succession.

Examples of sites where Japanese knotweed has been the first species to colonise recent lava flows include, Mt. Aso, Sakurajima Island, Mt. Nakadake, and Mt. Fuji. In primary successional stands on Mt. Fuji, researchers Tateno and Hirose, found that organic nitrogen, ammonium, and nitrate concentrations were 14, 4, and 2-fold higher, respectively, under R. Japonica stands than in bare soil (Tateno and Hirose 1987). Many early successional species, like R. japonica,

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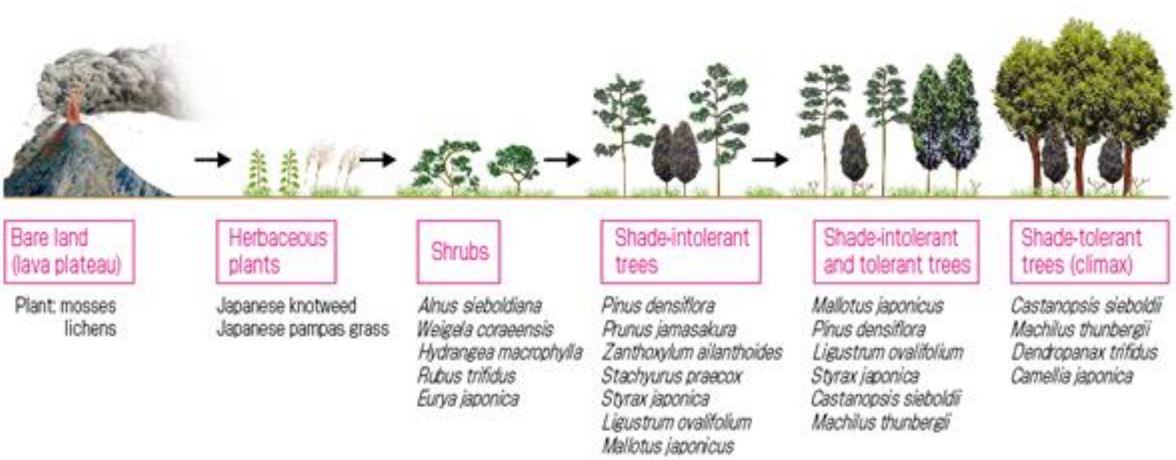
are known to increase soil formative processes, specifically by decreasing soil bulk density and increasing organic matter content, water content, and nutrient levels (Hirose and Tateno 1984). It is for this reason that, in the 1950s to 1970s, Japanese knotweed was used as an indicator species for fertile land.

Japanese knotweed facilitates succession in more ways than the improvement of soil qualities. In Japan, it is observed to exhibit a phenomenon known as 'central die-back', in which the shoot density (number of shoots in a given area) decreases in the centre of the patch, leaving a ring of knotweed with a small clearing in the centre. This is thought to be an intrinsic mechanism rather than any inter- or intra-specific competition. It is thought that the morphology of the older central rhizomes changes to produce fewer shoots than the newer rhizomes which are spread outwards to the sides of the stand. It remains unclear whether the rhizomes in the centre are alive or not, regardless, this clearing provides shelter and protection for seedlings of successor shrubs to grow.

Figure One (below)

Diagram of succession on a Japanese volcanic environment



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Section D

Knotweed on the move

Japanese knotweed is thought to have been introduced to Europe in 1849 by Philip Franz Von Siebold, a German physician and botanist in 1849. He travelled to Japan, teaching Western medical practices, and smuggling many species of Japanese flora and fauna into Europe. Siebold sent the plant to the Royal Botanical Gardens at Kew, England 2. Throughout the nineteenth century, Japanese knotweed was widely used as an ornamental. It became popular in the Victorian gardens of Europe. Deemed as the 'most interesting plant', it won a gold medal from the Society of Agriculture and Horticulture at Utrecht, in 18479.

Section E

Invasive species disrupt the native balance

There is a difference between an invasive species and an introduced species, and that is the damage caused. Japanese knotweed is a very fast-growing plant, and did not evolve alongside the native plants and animals we have here in the UK. Native UK plants must fight for the same resources such as light, water, and nutrients, as Japanese knotweed. Where at least one resource is limited, competition occurs within and between populations for the means of survival. Within a single community, one population is affected by other populations, the biotic factors, in its environment. Populations within communities are also affected by, and in turn affect, the abiotic (physicochemical) factors in an ecosystem. The adaptation mentioned earlier, the underground rhizome system, stores enough energy to allow Japanese knotweed to shoot up very fast early in the season, and shade out competitors with its large leaves.

Additionally, because Japanese knotweed did not evolve in the UK, the herbivorous pests such as caterpillars which target UK plants do not eat Japanese knotweed. Plants produce compounds called 'secondary metabolites' as a form of defence against insects. An example you might be familiar with is the bitter taste you get when you brew a cup of tea for too long – this bitterness is due to a compound type called tannins, which are produced to ward off hungry insects. Most insects are specially adapted to detoxify the secondary metabolites produced by their target plant species. This relationship is very specific because both insects and plants have evolved together, adapting to survive in their own niches. Most native UK insects cannot detoxify the secondary metabolites produced by Japanese knotweed leaves, and so the plant goes unharmed by native insects, giving it an advantage over the more tasty UK plants.

Figure Two

Dense foliage in a Japanese knotweed stand

Section F

Japanese knotweed reduces biodiversity in native populations

Biodiversity is a measure of how many different species live in an ecosystem. Ecosystems with higher biodiversity are more stable as they can easily adjust to changes. If something happens which alters the numbers of one species, there are usually knock-on consequences for other species in the community. Ecosystems with higher biodiversity have fewer species that depend on just one other for food, shelter and maintaining their environment.

Although a beneficial nursery on the exposed lava flows of East Asia, in its invaded habitats Japanese knotweed is considered a negative environmental weed. It is acknowledged to cause major ecological alterations to invaded communities by forming dense stands containing only Japanese knotweed and no other plants, known as mono-specific stands. The densely packed canes and broad leaves exclude the native vegetation (Holzner 1982).

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Competition with Japanese knotweed reduces growth of native flora and impacts faunal diversity. The foliage forms a dense canopy which causes a reduction in light levels by >90% at ground level, this restricts the growth of competing vegetation (J. N. Barney, unpublished data). The rhizome releases a series of secondary allelochemical compounds (see Resource 5), which affect the availability of mineral nutrients for native plants. The percentage cover of native vegetation, investigated via a 50 m transect through a R. japonica stand, showed a decrease from 100% where there was no Japanese knotweed, down to 0% within the Japanese knotweed stand. No native vegetation was able to penetrate the densely packed Japanese knotweed stand (Maerz et al 2005). The same research group found that there were fewer green frogs where there was Japanese knotweed. Under stands of R. japonica, the mineral content of the topsoil was significantly higher than under native species, especially in potassium and manganese (Vanderhoeven et al. 2005).

Japanese knotweed invaded sites have an increased abundance of fungi and amoebae, but a decreased abundance of bacteria. Fungi are thought to be favoured by the slowly decomposing knotweed litter and high tannin concentration (Mincheva et al. 2014, Tamura Tharayil 2014, Stefanowicz et al 2016). Some species of fungi can break down the complex organic substances in Japanese knotweed and release them back into the soil, which is important for nutrient recycling (Suseela et al 2016). Knotweeds are non-mycorrhizal plants and negatively impact mycorrhizal fungi (Stefanowicz et al 2016; Zubek et al 2016; Lavoie 2017).

Resource One Activities

Activities

1. Describe what is meant by a pioneer species.
2. A volcano has erupted in Japan leaving only a bare lava plateau. Different species begin to colonise the bare land, and these change over time. Put the following plant types in chronological order, A–D.

   Mature trees
   Mosses and lichens
   Shrubs
   Herbaceous plants (e.g. Japanese knotweed)

3. What is the role of ecological succession in a habitat?
4. Using the sources, suggest how succession can lead to more complex food webs.
5. Using the sources, suggest why biodiversity is important to an ecosystem.
6. What adaptations does Japanese knotweed have that make it better able to:

   colonise a volcano landscape
   compete against native UK species?

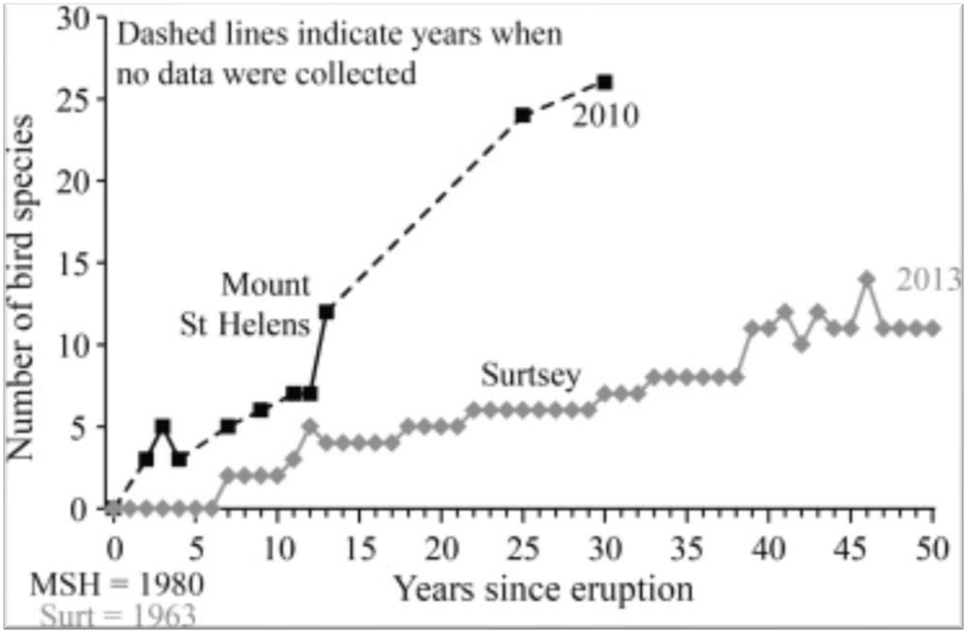
7. Using your knowledge from your wider course content, design your own experiment to measure the effect of Japanese knotweed stands on species diversity.

   Some possible things which you may want to think about using include: transects, ruler, tape measure, tubs to collect soil, pH meter, light meter etc

Resource One Activities

Activities

8. The following graph shows the change in species diversity over time in two locations, Mount St. Helens and Surtsey. Mount St. Helens is an active stratovolcano located in Skamania County, Washington, USA. St. Helens which erupted in 1980. Surtsey is a volcanic island located off the southern coast of Iceland, which erupted in 1963. Explain what is happening in the graph.



Resource One
Further Reading

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Explore

Independent research

1. For a short introductory guide to what Japanese knotweed looks like and its associated problems, watch this short video clip:
   [Japanese Knotweed]
2. For more information on Japanese knotweed, see CABI's website:
   https://www.cabi.org/japaneseknotweedalliance/what-is-japanese-knotweed/
3. For a recent thorough review on the environmental impacts of Japanese knotweed, see the following paper:
   Lavoie, Claude. (2017). The impact of invasive knotweed species (*Reynoutria* spp.) on the environment: review and research perspectives. Biological Invasions.
   19. 10.1007/s10530-017-1444-y.

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