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Invasive non-native species

Research suggests that the threat from invasive non-native species (INNS) is growing.[1–3] Biological invasions by INNS harm native species and habitats and can have economic impacts. Biosecurity measures can be adopted to prevent the introduction and spread of INNS. This POSTnote summarises the drivers and impacts of INNS and the measures needed to meet national and international environmental targets.

Overview

- Non-native species (NNS) can be introduced to a new area beyond their natural range by human activity. A minority of these are described as invasive non-native species (INNS) because of their negative impacts on the environment and economy.
- The impacts of INNS were estimated to cost the UK more than £1.8 billion per year in 2010. INNS drive losses of native species through impacts such as predation, competition, introducing diseases and altering habitats.
- The UK Government has international and national commitments to tackle INNS.
- The UK's 2019 report to the CBD found that despite some action, the impact, and risks from INNS in the UK remains significant.
- Most stakeholders say that more needs to be done to prevent the introduction and establishment of INNS. More action could avoid future costs.

Background

Invasive non-native species (INNS), or invasive alien species, are those that are introduced, intentionally or unintentionally, outside of their natural geographic range, causing environmental, social and/or economic impacts.[4–6] Any type of organism can be an INNS – including plants, animals, and microorganisms.[2] INNS are introduced to new areas via the international movement of goods and people.[7] More than 2000 NNS are established (reproducing in the wild) in the UK,[8,9] and some may provide economic, cultural or environmental benefits (PN 303).[10] However, an estimated 10-15% of these NNS have negative impacts and are designated as invasive non-native species (INNS).[11]

Biosecurity describes precautionary measures to prevent the introduction, spread and persistence of such harmful organisms (PN 660). Assessing if a NNS is 'invasive' is complicated as species may have both beneficial and harmful effects.[12,13] Determining whether a species is sufficiently harmful to warrant regulatory action may also involve subjective judgements that can be contentious.[12,14–19] However, emerging standards for INNS research support more objective analyses about what should be considered 'invasive'.[20,21]

Impacts of INNS

The impacts of INNS in the UK can be far reaching and long term. Harmful impacts and examples of each include:

- **Food security:** varroa mites weaken honey bees, reducing their pollination capabilities.[22]
- **Water supply:** zebra mussels block water pipes.[23]
- **Flood defences:** Chinese mitten crabs burrow into and damage river banks, increasing flood risks.[24]
- **Recreational activities:** floating pennywort block waterways, to the detriment of water sports and fishing.[25]
- **Buildings & infrastructure:** Japanese knotweed damages pavements and devalues buildings (PN 303).
- **Health & wellbeing:** oak processionary moth hairs can cause rashes, asthma attacks and anaphylactic shock in humans and animals (PN 303)
- **Ecosystems** muntjac deer graze in woodlands preventing tree regeneration, which in turn affects other wildlife, including birds and butterflies.[26,27]

The United Nations Convention on Biological Diversity (CBD) has identified INNS as one of biggest drivers of native biodiversity loss worldwide.[5] INNS can drive the decline of native species in a number of ways, including through competition,[28–34] predation,[35–39] disease transmission,[40–43] and habitat alteration, which can displace or otherwise threaten native species.[44–51] However, the financial impacts of INNS on biodiversity, which can be thought of as a strategic and financial asset in itself (PN 667), is difficult to assess. Despite this, the economic cost of INNS in the UK is estimated to be a least £1.8 billion.[52] Most of these costs are incurred through damage (for example, costs for: repair, agriculture, forestry and fisheries production losses, or medical care), with a smaller fraction spent on reactive management, and a smaller fraction still, spent on proactive management.[53] As information is not available for all species, all places, and all types of direct and indirect costs, these figures are likely to be an underestimate.[52] The UK is also responsible for biodiversity in its overseas territories, many of which are islands and have been particularly impacted by INNS (Box 1).

Government commitments to tackle INNS

As part of the Government's Environmental Improvement Plan,[68] and under the Bern Convention,[69] and the CBD,[70] the Government has both international and national commitments to tackle INNS. Under the proposed 2022 Biodiversity Target 6 of CBD's global biodiversity framework, Parties must manage pathways of INNS introduction to prevent or reduce their rate of introduction and establishment by at least 50%. They must also control or eradicate INNS to eliminate or reduce their impacts, focusing on priority species and sites.[71] The UK's sixth national report to the CBD in 2019, found that the UK had 'made progress' towards the previous INNS target but 'at an insufficient rate' and highlighted that 'despite strong action the number of INNS establishing in the UK has remained constant in terrestrial environments and increased in freshwater and marine environments'. The report concluded that 'the impact and risks from INNS in the UK remains significant',[72] despite the implementation of the GB INNS Strategy.[11,73] The Environmental Audit Select Committee's (EAC) 2019 report on INNS also concluded that the Government had missed targets, and INNS were not receiving appropriate priority or funding.[67]

Box 1 INNS in the UK Overseas Territories (UKOTs)

The UKOTs have 94% of the biodiversity that the UK is responsible for. They are home to endemic species that are found nowhere else in the world (PN 427). This includes endemic species (those found only in a certain area) that have evolved in isolation, and that have small populations, and less genetic resilience to diseases.[54,55] They are thus particularly vulnerable to the impacts of INNS:

- In all UKOT islands, rats have depleted or decimated, native species, particularly breeding sea bird colonies.[56–58]
- In St Helena, invasive non-native plants threaten native cloud forests, which are crucial for island water security.[59]
- In Bermuda, American crows reduce crop yields, raid native bird nests and scatter rubbish,[60] and the invasive lionfish consumes vast quantities of native reef fish and invertebrates, including those of ecological and economic importance in the region.[61,62]

The UK has an international commitment to conserve UKOTs' biodiversity. Large-scale eradication and management projects can protect and restore biodiversity,[63] but the UKOTs are often ineligible for domestic and international funding.[64] UKOT's may apply for Darwin plus initiative (DPI) funding for projects to tackle INNS, funding for which has recently increased.[65] However, DPI projects are limited to a maximum three year period.[66] This results in a high reliance on private funding and charities (such as the RSPB) to finance larger long term projects.[67]

Drivers of INNS introduction and spread

Evidence of species movements from fossil records show that over the last 500 years species have moved around the globe faster and in greater numbers than ever before.[74] There are over 2000 NNS already established in the UK.[8,9] On average, each year 10-12 new NNS arrive and establish in the UK. At least one is predicted to become invasive, year upon year, compounding the problem.[11]

Trade, travel, and tourism

Species invasions are shaped by trends in trade and transport. NNS are brought into the UK accidentally, as stowaways in cargo, ballast water, ship hulls, fishing and water sport equipment, on clothing or vehicle tyres; and deliberately, for agriculture, forestry and fishery, and by the ornamental and amenity plant and pet trades.[2,75] Consequently, shifts in biological invasions tend to mirror global economic forces like shifting trade volume and frequency.[76] The number of INNS within a country is highly correlated with merchandise imports,[77] and the prevalence and density of INNS is correlated with levels of development and trade.[7,78] Some countries, such as New Zealand, have been able to effectively tackle INNS through biosecurity measures (Box 2), although differing trade contexts make direct comparisons between countries difficult.

Environmental change

INNS tend to be highly adaptable opportunists, with rapid growth and reproductive rates, and can tolerate a broad range of environmental conditions.[79] For example, invasive non-native plant species often colonise disturbed or previously developed land, such as disused urban areas.[80,81] Environmental changes, such as climate change, landscape and habitat change, and pollution, could create conditions that favour existing INNS,[82–85] or may facilitate NNS becoming invasive.[86–89] The arrival of INNS in a habitat can create novel communities of species, which occur in combinations or abundances that did not previously exist.[90–92] Some researchers suggest this is inevitable when native communities cannot be restored.[93,94] Others are concerned that as the native and new species have not co-evolved, it could result in unstable environmental outcomes.[95,96]

INNS time lags

Most of the NNS in the UK are not invasive.[11] In those that are, there can be a time lag (sometimes decades) between a NNS establishing in an area and becoming invasive.[97–99] This lag can be due to the time taken for a species to reproduce and populate, or genetically adapt to, an area.[100] Newly created environmental conditions could also favour a NNS, providing a window of opportunity for the NNS to become invasive.[100,101] Invasional time lags have previously been recorded for UK garden plants and could provide a source of future invasions.[102–104] Once an INNS has established, it may also facilitate the establishment of other INNS.[105,106 107] For example, zebra mussel invasion may facilitate killer shrimp invasion, by providing habitat and a food source.[108,109]

Tackling INNS: the regulatory hierarchy

The GB Invasive Non-native Species Strategy (2015) provides the framework within which to coordinate biosecurity and management across governments and the devolved administrations, their related bodies, and key stakeholders.[11] Northern Ireland is part of a separate INNS biosecurity strategy

Box 2: Biosecurity in New Zealand (NZ)
NZ is seen as a global leader in policy development and biosecurity is a national priority.[2,110–112] NZ operates a strict precautionary approach where only listed species can enter.[113] NZ's Biosecurity 2025 strategy objectives include:[114]

- 75% of adults will understand what biosecurity is and why it is important.
- 100,000 New Zealanders will regularly take action to control INNS in their communities.
- 90% of relevant businesses will actively manage pest and disease risks associated with their business.
- At least $80m (NZ) of public and private investment will be fed into biosecurity research.
- There will be a 'citizen's army' of 150,000 people with identified skills for support during biosecurity incursions. Training the same proportion of the UK public in biosecurity would equate to a 'citizen's army' of 2m people and cost £83m per year.[67]

and is also subject to the EU Invasive Alien Species Regulation (see below).[115] The GB Strategy is currently being revised (PN 439).[116] The strategy is based on the CBD's three stage approach of prevention; surveillance, early detection and rapid response; and long term management (PN 303).

Prevention

Pathways of entry are the routes of introduction and spread of INNS. Some pathways of entry may present greater risks than others.[117] In 2019, Defra published its comprehensive pathway analysis and identified 10 priority pathways by which INNS were being introduced to the UK: hull fouling,[118] ornamental plants and their contaminants[119,120] ballast water,[109,121] contaminants of fishing equipment,[122] other stowaways,[123] contaminants of aquaculture animals,[124] ornamental escapes (from wildlife collections),[125] pet escapes,[126] and zoo or botanic garden escapes.[73,119] The most time and cost-effective way to control INNS that avoids ethical and welfare issues around management, as well as environmental harm, is preventing their arrival.[98,127–129] Pathway action plans (PAPs) aim to prevent or manage the risks associated with particular pathways. As part of the UK INNS Strategy, PAPs for angling, recreational boating, and zoos are in place, with more in production.[130] Prevention measures include import bans of high-risk species, border inspections, enforced quarantines, monitoring, and encouraging personal biosecurity at borders.

In their analysis, Defra identified the horticultural trade as a priority pathway of entry for INNS into the UK. Garden plants can escape from gardens and become invasive, or harbour INNS in or on the soil they are imported in.[131] The complexity of soil biology (one handful of soil possibly holding thousands of species (see PN 601)),[132,133] is not yet fully characterised. However, academics and NGOs have raised concerns about the volume of NNS that could be introduced via soil imports.[120,134–136] GB's Plant Biosecurity Strategy 2021 aims to tighten restrictions on soil imports and encourage domestic tree and plant nursery production over external imports to circumvent the import of INNS and their risks.[137,138]

Public awareness campaigns
As several of the key pathways of INNS introduction involve the public, the UK Government launched two targeted campaigns for groups at risk of transporting and spreading INNS:

- The **Be Plant Wise** campaign encourages gardeners to 'Know what you grow', 'Stop the spread' and 'Compost with care' to reduce horticultural escapes.[139]
- The **Check, Clean, Dry** campaign encourages recreational water users (anglers and boaters etc.) to check, clean and dry their equipment in-between trips to reduce the risks of spreading invasive aquatic species between water bodies.[140]

Surveys by the Angling Trust found that 50% of anglers now follow Check, Clean, Dry, and research found an increase in positive behaviours associated with the campaign.[141] New Zealand's Check, Clean, Dry campaign, which benefited from higher funding, found that 88% of high risk water users were able to identify actions to help stop the spread of INNS.[142] The EAC report highlighted the need for a broader, more sustained approach to biosecurity campaigns in the UK.[67]

Controls on imports
International agreements and laws provide standards, guidelines and recommendations surrounding INNS management and prevention.[143] However, domestic legislation in most countries often aims to control imports rather than exports.[144] The UK has a blacklist of species that are currently illegal to import into the UK,[67] but this approach is less stringent than some countries acknowledged to have more effective biosecurity frameworks (Box 2), (PN 439). Despite regulations, prohibited species still enter the UK and are distributed to the public.[145–148] This is often done in ignorance of regulations or due to INNS being misclassified as a legal species.[149] E-commerce is largely unregulated so may be a key route of illegal importation of INNS.[150–153] In line with EAC recommendations, in 2022, the GB Non-native Species Secretariat began piloting the establishment of an INNS inspectorate, whose roles will include pre border, border, and post-border interception, ensuring compliance with regulations, and promoting good biosecurity practice across sectors.[67]

Existing legislation
The principal pieces of legislation regarding INNS in GB are:

- The Wildlife and Countryside Act (1981), see PN 303.[154] Section 23 of the Infrastructure Act (2015) inserted Schedule 9A into this act to ensure landowners take action on INNS or permit others to prevent their establishment and spread.[155]
- The Wildlife and Natural Environment (Scotland) Act 2011.[156]
- The Invasive Alien Species (Enforcement and Permitting) Order (2019), which retains in UK law the EU Invasive Alien Species Regulation (1143/2014) in England, Wales, and parts of Scotland. It lists species of concern and rules to prevent their introduction and spread. Enforcement regimes includes criminal sanctions and licensing and permitting provisions.[157]
- The Crime and Policing Act (2014) allows local councils and police to issue Community Protection Notices to individuals or businesses to control or prevent the spread of an INNS. [158]

Stakeholders have raised concerns that enforcement of current INNS legislation is insufficiently resourced.[67] The RSPCA has also highlighted practical difficulties translating the legislation into action. For example, the original invasive alien species legislation had to be changed as it criminalised any transport of listed INNS of special concern, making it impossible for the RSPCA to respond to call outs regarding these species.[157,159]

Surveillance, risk assessment and rapid response

Efficient surveillance relies on rapid and effective information exchange at international, national and regional levels, to identify which INNS are in-coming and make adequate preparations.[160] However, some countries lack monitoring resources and data,[161] and political and economic obstacles can hamper communication between nations, as policies aimed at addressing INNS risks can be in conflict with trade.[144] If an INNS evades border controls, quick identification and implementation of rapid response protocols may result in the eradication of a species before it becomes established.[162] However, aquatic environments are both particularly vulnerable to invasion and difficult to monitor, and INNS here may not be detected until after they have established and spread (Box 3).

In some cases, using tools such as citizen science (Box 4), environmental DNA (eDNA) technologies, and epidemiological and species distribution modelling can aid in surveillance:

- **eDNA technologies** can be employed to detect whether or a not a species DNA is present in a body of water thereby indicating its presence.[163–165] Although environmental conditions can degrade or disperse DNA,[166–168] surveillance using eDNA can be faster and cheaper than conventional sampling methods, but cannot replace them completely – the two approaches being complementary.[169–171]
- **Epidemiological modelling** capitalises on the similarities between species invasion and the spread of disease, in order to understand more clearly how they will spread.[172]
- **Species distribution modelling** can calculate the likelihood of a species establishing in a specific area under present and future environmental conditions.[173,174]

Horizon scanning exercises predict future threats from INNS not already present in the UK.[162] Risk assessments of threats can then be used to inform surveillance, rapid response plans, and regulations to limit the spread of a INNS before they become established.[11] To remain useful risk assessments need to be regularly reviewed and updated.[144] The UK has contingency plans for the arrival of some INNS,[175] but there is no resourcing available to implement them should the species arrive.[67]

Box 3: The vulnerability of aquatic environments

INNS pose a significant threat to marine and freshwater environments (PN 303). Pathways include aquaculture and ballast water.[176–178] As 90% of the world's trade is carried by ship, marine environments are particularly exposed.[179] Hull fouling and ballast water provide pathways for INNS to spread throughout the marine environment.[11] Under the Ballast Water Management Convention (BWMC), adopted in 2004, all ships are required to manage their ballast water and sediments, and will eventually be required to install on-board water treatment systems to control the spread of INNS through ballast water.[180,181] Despite playing a key role in negotiating the convention, the UK has repeatedly delayed ratifying the BWMC.[182] To date, 89 International Maritime Organisation Member States have acceded to the Convention, representing over 91.2% of global shipping tonnage,[183] and where implemented it has been found to significantly reduce the rate of aquatic invasions.[184] Once an INNS has established in connected aquatic environments (marine or rivers) it is very difficult to eradicate or contain, and is likely to spread rapidly to new locations.[185–187]

Long term control and management

The EAC report found a lack of clear lines of responsibility for managing INNS in the UK.[67] Landowners have legal obligations to manage certain INNS, particularly in relation to preventing spread,[188] but they may be unwilling to bear costs. In England, under Tier 2 of the Environmental Land Management Scheme, payments will be available for landowners to manage INNS identified as a local environmental priority (PN652).[189] Limited resources mean that the Government only directly supports the management of about 20 (10%) of the most invasive INNS in GB.[11] Long-term management includes large scale eradication, containment, control, and mitigation, and can include biocontrol programmes.[11] Biocontrol reassociates a species with its natural enemies (diseases or predators) to control a population.[190] Biocontrol organisms are assessed to ensure they do not have any unwanted side effects,[191] and their release must be approved Defra and the devolved authorities, as advised by the UK's Advisory Committee on Releases to the Environment.[192] Biocontrol can work on a continental scale to reduce populations, with successes in Australia.[193,194] Since 2010, Defra has approved the release of four INNS biocontrol agents: a psyllid (insect) against Japanese knotweed;[195,196] a rust fungus against Himalayan balsam;[197] a mite against Australian swamp stonecrop,[198] and a weevil against floating pennywort.[199]

However, the restoration of environments post INNS management intervention is often overlooked. Sometimes INNS can alter habitats to the extent that even after their removal native species do not readily re-colonise the area,[200] and interventions to restore habitats may be required.[200] For example, Rhododendron acidifies soil, making it harder for native species to re-establish.[201] Ecosystem management to restore habitats and reduce degradation may also increase the resilience of natural communities to INNS invasions.[202–205]

The economic benefits of INNS regulations

Currently, 0.4% of available biosecurity funding is spent on INNS (~£900k per annum). Funding for INNS management in the UK tends to be short lived, and for individual projects rather than directed towards routine actions to avoid future costs.[67] Stakeholders have highlighted INNS biosecurity underfunding, with most resources spent on established species as opposed to preventing INNS arriving and establishing.[67] NGOs and academics state potential savings could be made by taking such proactive measures.[206] Wildlife and Countryside Link estimate that an additional Government investment of £6m per year into INNS biosecurity would save ~ £2.7b over a 20-year period.[129]

Box 4: Citizen science and surveillance

The value of early detection and surveillance is exemplified by the UK Government's successful eradication and control of the Asian hornet.[67] The Asian Hornet Watch App (developed by the Government) allows the public to report sightings of Asian hornets, which when verified as credible, result in rapid response and eradication.[207] Continued control of Asian hornet arrivals in the UK would not be possible without public participation in surveillance.[208] A similar citizen science project, Plant Alert, was set up for gardeners to warn about invasive plants before they become a problem.[209] However, it has no financial support, relying entirely on volunteers, and is not an official government tool.[210]

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