An Analysis of the Effectiveness of Law and Policy in Assisting in Control and Prevention of Non-Native Invasive Species Spread in England and Wales.

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July 2021

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Abstract:

Non-Native Invasive Species (NNIS) are recognised globally as a significant threat to biodiversity. As part of an island nation with longstanding global trading links, England and Wales are particularly susceptible to the threats that NNIS pose. Although current law and policy identify these threats, gaps in knowledge and a clear cohesion between science and law is currently a limitation. This study reviews materials from law, policy and science, as well as incorporating stakeholders' opinions to identify the best possible practice in the future of NNIS control.

A systematic review addressing the study question *"how effective is law and policy in assisting in control and prevention of non-native invasive species spread in England and Wales?"* was conducted using literature from Web of Science and supplemented by other databases. Following from this a selection review of NNIS in England and Wales was conducted to identify species frequently mentioned in relevant research that have a substantial detrimental impact on social, economic and/or environmental factors to use as case studies. Three high profile species from varying classes were chosen to investigate in more detail how law and policy is applied: Japanese knotweed (*Fallopia japonica* Houtt), North American grey squirrel *(Sciurus carolinensis* Gmelin) and North American signal crayfish (*Pacifastacus leniusculus* Dana). To ensure a detailed review of these species was undertaken, and a systematic approach was also used.

Questionnaires and semi-structured interviews were conducted in this study to target appropriate stakeholders from different fields of work including governmental representatives, NGOs, agricultural workers, and academics. These questionnaires and interviews aimed to investigate the opinions on key NNIS law and policy in place and any issues with current management of NNIS in England and Wales. This primary research incorporated important opinions from those directly impacted by NNIS, as stakeholder knowledge and experiences are key to understanding the gaps in current NNIS law and policy. Results from this were analysed using the NVivo software and compared to the results from the literature review.

The study found, that to effectively control NNIS, law and policy must consider biosecurity and prevention, public involvement, scientific research into effective control measures and enforcement efforts. However, several issues with these areas were identified. Current public awareness of NNIS is poor, highlighting the need for the government to invest more into education campaigns. Better education can in turn help improve biosecurity. It was highlighted that scientific research into risk assessments is a key component in aiding preventative policy, and research into control measures crucial to ensuring NNIS control programmes are an effective use of resources. Enforcement was determined to be the least effective area, with very little evidence of law and policy being enforced to prevent illegal NNIS spread. It is crucial that enforcement efforts are improved to achieve effective NNIS management and ensure law and policy is implemented in England and Wales.

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Acknowledgements

Firstly, I would like to thank my supervisors Tilak, Iain and Kathy, and Bournemouth University for all the support and help throughout my studies. I would also like to extend a massive thank you to the stakeholders who participated in my questionnaire and interviews for taking the time to help with this study. I wish to thank all my friends for their continued support, and my amazing brother and sister for always believing in me and reminding me to believe in myself. I want to thank my incredible partner for his unrelenting support, endless cups of tea and for reminding me to smile when the going got tough- I could not possibly have done this without you. And finally, I want to thank my parents. You are my rocks, and I cannot express how grateful and lucky I am to have you supporting me.

Glossary

BES – British Ecological Society

CBD – Convention on Biodiversity

DAISIE – Delivering Alien Invasive Species Inventories for Europe

DEFRA – Department for Environment, Food and Rural Affairs

IUCN – International Union

NGO – Non-Governmental Organisation

NNIS – Non-Native Invasive Species, any species that is not a normal resident within an area, which has been shown to cause detrimental impacts to the surrounding environment. This definition is the same for Invasive Alien Species (IAS)

NNSS – Non-Native Species Secretariat

SD – Standard Deviation

SDM – Species Distribution Model

SE – Standard Error

1 Introduction

1.1 What is a non-native invasive species?

A non-native species is defined as "a species, subspecies or lower taxon, introduced (i.e. by human action) outside its natural past or present distribution; including any part, gametes, seeds, eggs, or propagules of such species that might survive and subsequently reproduce" (NNSS 2018).

Although many non-native species that have been introduced have had non-consequential or even beneficial impacts on native ecosystems, there are those that have been introduced that have had a detrimental impact on the environment, human health and/or lifestyle across the globe (Manchester and Bullock 2001; IUCN 2018; NNSS 2018;). These species are referred to as non-native invasive species (NNIS) and can be any animal or plants that bring changes such as to interspecific competition, the spread of disease, and predation of native individuals. These changes can trigger any number of alterations to the native ecology, for example habitat structure, species richness, behaviour patterns and ecosystem productivity (Blackburn et al. 2014). These drivers result in NNIS being considered to be the second greatest cause of species extinction (Bellard et al. 2016). However, the impacts of NNIS are not only felt by native ecology, as research shows that they can also pose threats to livelihood and health of human stakeholders (Vanderhoeven et al. 2017).

1.2 Non-native species in England and Wales

Non-native species were initially brought into England and Wales for a variety of different reasons but primarily for ornamental purposes, agriculture, biological control or as stowaways (Manchester and Bullock 2001). With these, came a number of non-native invasive species (NNIS), which have, and still are causing detrimental impacts (Blackburn et al. 2014; Collier 2018).

Several factors, such as globalisation and being a small, highly populated island ecosystem make England and Wales particularly vulnerable to the spread and impacts of NNIS (Veitch and Clout 2002; Reaser et al. 2007; Keller et al. 2011; Amano et al. 2016).

The impacts of globalisation are increasing throughout our world. Although there are many benefits from globalisation, which is generally considered to have a positive impact on the economy, it has also been observed that the increased interconnectedness has also assisted in the spread of many NNIS (Reaser et al. 2007; Hulme 2009). The impacts of NNIS are considered one of the greatest threats to native biodiversity and this threat is growing more extensive over time (Keller et al. 2011; Amano et al. 2016). As a leading country with longstanding global trading links for hundreds of years, Britain as a whole is a highly connected and leading example of globalisation (Held et al. 1999; Hirst and Thompson 2000). Therefore, as globalisation becomes more prevalent across the world, furthering the spread of invasive species, effective methods for NNIS control in England and Wales will become ever more important.

Island ecosystems are often limited yet unique compared to continental ones. The stretches of water that isolate an island from other landmasses result in genetic drift and other drivers

of allopatric speciation, leading to divergent biodiversity; native species are often more sensitive to change and are highly likely to be endemic to their islands as a result (Reaser et al. 2007). Research also suggests that the impacts of NNIS are the leading cause for the extinction of native wildlife in island ecosystems, emphasizing the importance of protecting island nations from non-native species (Veitch and Clout 2002; Reaser et al. 2007). The high population density of England and Wales also makes it more susceptible to NNIS spread (Spear et al. 2013, Early et al. 2016). England and Wales are therefore particularly vulnerable to the impacts of NNIS, making it imperative to effectively control the spread of NNIS to protect our native wildlife.

Furthermore, although England and Wales are not home to many endemic species, achieving effective management of the threats to NNIS on our shores could help to set example for other jurisdictions, as well as improvements in law and policy aiding British Overseas Territories, many of which have unique, endemic ecosystems.

Research has been undertaken to assess the impacts of invasive species in England and Wales and methods of categorising and undertaking risk assessments for them (NNSS 2005; Baker et al. 2005; Blackburn et al. 2014). However, a comprehensive understanding of the impacts of different NNIS in England and Wales still lacking in the literature and an urgent need for more comprehensive and detailed assessment is key to going forward with better and more efficient management of the non-native invasive species (Vanderhoeven et al. 2017).

When discussing NNIS in this study, the word "control" is used when referring to the management of NNIS. When referring to NNIS, the CBD defines the term "control" as: "suppression, containment or eradication of a pest population" (CBD, 2006). Use of the word control in this study follows a similar interpretation, with the word "control" referring to any management efforts used in order to reduce or eliminate NNIS populations from an area and/or prevent the introduction/further spread and impacts of NNIS across England and Wales.

1.3 Law and Policy in England and Wales

There can be no question that environmental regulation plays a significant role in British law and policy. Advances in environmental law and policy have been made in England and Wales, particularly since joining the European Union in 1973 (Burns and Carter, 2018). However, current laws and policies still contain flaws when concerned with protecting the environment and environmental concerns are often neglected in key political debates regarding England and Wales's future (Burns and Carter 2018).

For policymakers to make well-informed decisions regarding NNIS, scientific research must be available to them in a clear, understandable manner and practitioners must use this research when creating law and policy. Some studies state that this has not always been the case in the past, with research not being incorporated into law and policy by practitioners, (Reaser 2007; Walsh et al. 2014). However, the government has funded research to better inform policymakers (Walsh et al. 2014). Furthermore, governmental campaigns such as "Check, Clean and Dry" have been funded in order to promote good biosecurity practice s, with research showing that the number of anglers that clean equipment regularly since the campaign was launched in 2011 has increased by 15%, with an uptake of biosecurity practices being at 80% (Smith et al. 2020). This is just one example of the influence that governmental campaigns and policy can have of effective NNIS control measures,

highlighting the importance of government authorities such as DEFRA and the Non-Native Species Secretariat in achieving effective NNIS control. This study will review the current law and policy alongside scientific research and the experience of stakeholders to establish whether efforts are working in informing policymakers, to ensure that the current systems in place are achieving the best possible results in NNIS management.

1.4 Location of Study

The primary law addressing NNIS in England and Wales, is the Wildlife and Countryside Act (1981), therefore, a key focus of this study will be on the effectiveness of this Act in relation to NNIS control.

Many organisations such as the Non-Native Species Secretariat (NNSS) and the Great Britain Invasive Non-native Species Strategy focus on the entirety of Great Britain. However, since 2011, the Wildlife and Natural Environment Act gave Scotland powers as a separate entity when managing NNIS. Furthermore, Scotland also has its own individual groups (NNS Action Group and the Statutory Group on NNS) as well the SEPA, which acts as a regulatory body for the nation instead of the Environment Agency, which only covers England and Wales. Likewise, Northern Ireland are regulated by the NIEA. Some law, policy and literature mentioned in this study encompass the entirety of Great Britain, however it was decided to focus this study in England and Wales, as information and viewpoints of stakeholders from the Environment Agency will be included in the research.

2 Aims and objectives

This study aims to assess the current effectiveness of the law and policy in assisting the control of non-native invasive species, using high profile non-native invasive examples of a variety of flora and fauna within England and Wales.

To achieve this, the following objectives were created:

1. Through the use of systematic review, identify and analyse the key factors affecting the effectiveness of law and policy in assisting in NNIS control and prevention in England and Wales.
2. Identify high profile case study species and evaluate the effectiveness of British law and policy in managing these species.
3. Using questionnaires and semi-structured interviews, determine the views of stakeholders in England and Wales on the impacts of the case study invasive species, as well as their perspective of current control measures and the effectiveness of current law and policy surrounding NNIS.
4. Evaluate the research results from the systematic review together with the opinions of stakeholders to identify any gaps in current NNIS management and law and policy in England and Wales.
5. Make recommendations of changes to relevant policy, incorporating the results from the systematic review of literature, case study reviews and stakeholders' viewpoints.

Chapter 1: Systematic and Case Study Reviews of the Effectiveness of Law and Policy in Preventing and Controlling NNIS Spread in England and Wales

In this chapter a systematic review method is used to investigate literature surrounding law and policy in England and Wales to help assess its' effectiveness in assisting in prevention and control of NNIS. Following on from this, three high profile species are used to investigate the law and policy in more depth. The case studies are literature reviews, but they aimed to use a systematic approach; to help make sure research was comprehensive and repeatable.

3 A systematic review of NNIS law and policy

3.1 Introduction

This section will first detail the major laws and policies in place, then assess their effectiveness by using Web of Science (as well as other databases) to systematically review the relevant literature.

3.2 What is a Systematic Review?

As systematic review is a method used to identify and analyse the literature surrounding a clearly formulated question in a comprehensive and repeatable approach (Khan et al. 2003).

Systematic reviews were initially brought in for medical research to help studies encompass all the relevant research to answer specific questions within studies (Bilotta et al. 2014). However, research has also shown that this method can be used effectively for reviews in the environmental sector (Pullin and Stewart 2006; Graham et al. 2018; Kapitza et al. 2019; Shackleton et al. 2019; Martin et al. 2020). In contrast, literature reviews can often show bias and a lack of rigour in their reporting, an issue that can hinder the devising of effective policy (Tranfield et al. 2003). These issues that can be resolved by use of a systematic review, which adopts a repeatable, clear process that aims to encompass all relevant literature and minimise bias, ensuring research is comprehensive and reproducible.

3.3 Reasons for doing a Systematic Review

As well as being shown to be a good practice, not just for medical articles but for scientific research too, a systematic method was considered appropriate for this study for several reasons:

- Other scientific literature has demonstrated the systematic review method to be an effective tool in research.
- As a study investigating the effectiveness of policy and law, it was essential to minimise bias in the study and have a comprehensive critical analysis with reliable conclusions.

- Should any major changes occur to NNIS law and policy, it was important to ensure work could be repeatable to review again with new legislation changes considered.

3.4 Limitations

The limitation of a systematic review method is the time required to complete the process. Often a panel of researchers will be formed to undertake the process and gain consensus, so for an individual researcher, the systematic review process is considered extremely difficult to complete (Tranfield et al. 2003). Given the limited timeframe due to the wide-ranging topic areas covered in this study, as well as not having a panel of researchers, it was decided to do a focused systematic review, with supplementing literature reviews for the case studies. The systematic review aimed to address the key question for this study: "How effective is law and policy in assisting in NNIS control in England and Wales?". This study took example from scientific papers that used a systematic method effectively (Graham et al. 2018; Kapitza et al. 2019; Shackleton et al. 2019; Martin et al. 2020) to ensure the search criteria and method was standardised. The law and policy was then investigated further by systematically approached literature reviews of the case study species.

3.5 Methods

The primary database used for systematic searches was Web of Science due to the flexibility of search criteria with detailed findings. Additional literature searches were also completed on Scopus, Science Direct, Google Scholar as well as the use of Westlaw and ENDS Report when the searches directly focussed on law and policy. In the case of full Boolean searches not being possible on a search site (e.g. there is a maximum limit of Boolean terms allowed on Science Direct), the most commonly used scientific term and most important criterion was used (Martin et al. 2020). The wide use of different sites and detailed search criteria helped to create a more comprehensive method.

A wide range of vocabulary has been used in literature when referring to non-native invasive species (Shackleton et al. 2019). This had to be considered when commencing the systematic approach, as otherwise research could be missed, simply because of using terms such as "invasive alien" as opposed to "invasive non-native". To avoid this, inclusion criteria were presented in Table 1, listing the alterations of each term to be included in the systematic searches. Similarly, various phrases such as "Britain", "England" and "Wales" were also included. Experimental searches using Web of knowledge and Scopus identified exclusion criteria of topics that were outside of the study field such as "New England" and "New South Wales". This exclusion criteria was also added to the final searches.

Before beginning the systematic review process, a clear outline of the research criteria had to be decided. The method described by Boland et al. (2014) for conducting an appropriate systematic review was utilised in this study to better incorporate the systematic approach adopted in this study. Table 2 was created to clearly identify what the review was aiming to achieve.

For the research question to be addressed, both the law and science had to be considered. As the focus was on cases from England and Wales, "Britain" and "UK" was included, but literature focussed in "Northern Ireland and "Scotland" were excluded. Research that was

undertaken prior to the Wildlife and Countryside Act 1981 was also excluded, as this study only aims to look at the impacts of NNIS after this law was passed.

The terminology listed in Table 1 were collated from undertaking background research for similar systematic reviews surrounding NNIS (Roberts et al. 2013; Warren et al. 2017). The terms for "invasive" and "alien" non-native species are also the same as those used in British law and policy.

However, other terms such as "exotic" and "non-indigenous" were found to also be used in more recent systematic reviews (Dueñas et al. 2021). When a check was undertaken to establish how many more results were returned with these extra search terms, there was no major difference in results was observed, with "invasive" frequently being paired with non-native or alien but less so with the other terms, meaning much of this returned literature focused on invasive introductions, so was not relevant to the study. Relevant literature from searches of "exotic" and "non-indigenous" was later included however, as additional sources (Figure 2). In future studies of this nature, it is recommended that these terms should be included initially to ensure a more comprehensive systematic review.

Table 1: Base search terms used in the systematic review of NNIS in England and Wales

Terminology		
Invasive*	Species	UK
Non-Native*	Organism*	Britain
Alien*	Animal*	British*
	Plant*	England/English
	Flora	Wales/Welsh
	Fauna	United Kingdom (Excl. studies specific to Northern Ireland and Scotland)

Table 2: Aim criteria of review of NNIS in England and Wales

Who	**What**	**How**	**Where**
Academic researchers (inclusive of journal articles, legal documentation, grey literature books and reports available from a wide selection of resources)	Literature relating to the effectiveness of law and policy in controlling non-native invasive species (in accordance with Schedule 9 of the Wildlife and Countryside Act 1981)	Through systematically approached literature reviews, predominantly using Web of Science and Scopus and supplementing with various other search sites, to identify suitable high profile case species and then assess effectiveness of policy using these case species.	England and Wales

The flow diagram below (Figure 1) demonstrates the method used to determine which literature met the relevant criteria for this study. For results from systematic searches, the flow diagram was used to categorise the results further and help keep the focus on the question, allowing the most relevant and useful articles to be identified.

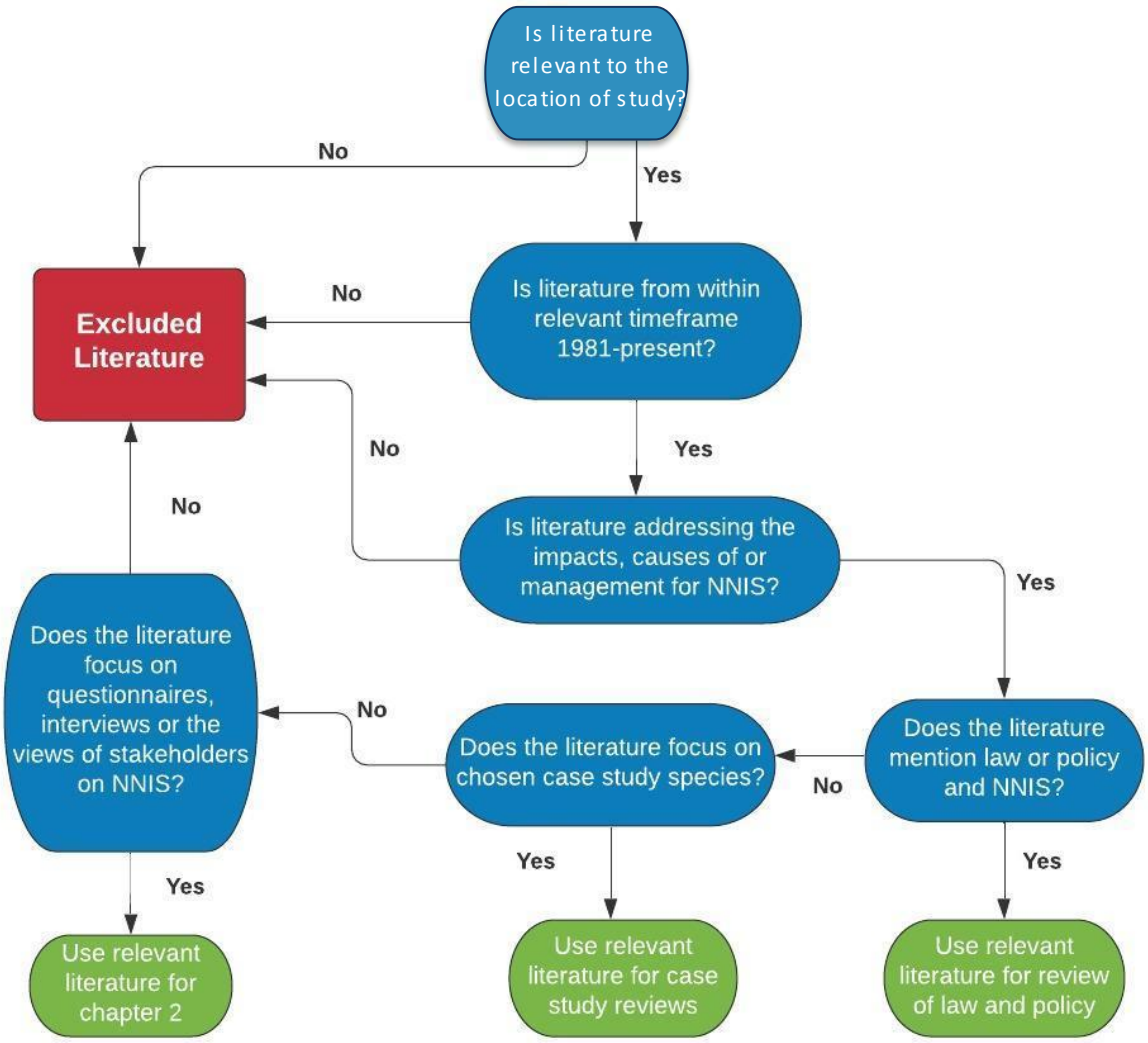


Figure 1: Flow diagram of selection review search criteria. Where results were not considered relevant to the systematic review, they were assessed for eligibility for the case study reviews or as useful literature to use for Chapter 2 before being excluded from the study.

3.6 Law and Policy

Table 3: Summary of key NNIS Laws, giving a brief description of how each law works and highlighting their positive and negative attributes.

Law	Description	Positives	Negatives
Wildlife and Countryside Act (1981)	Prohibits the release of species that are "not ordinarily resident in and is not a regular visitor to England and Wales in a wild state" into the wild. Operates using a Schedule 9 Blacklisting approach.	-This sets out the key legislation surrounding NNIS control. It is one of, if not the most important legislative instrument in British law (Manchester and Bullock 2001)	-The effectiveness of this law has been hindered by its confusing language, limited publicity, and lack of enforcement (Keller et al. 2009). - Use of the Schedule 9 blacklist poses the risk that unlisted species will be left unregulated, allowing them to spread in England and Wales (Dehnen-Schmutz 2011; Garcia-de-Lomas and Vila 2015)
Anti-social Behaviour Crime, and Policing Act 2014	This act is designed for the public to report a nuisance in their neighbourhood. It was amended to allow people to report NNIS as a public nuisance using this act.	-Can be raised to address issues of NNIS spreading onto neighbouring land -Can be raised by the public as well as relevant authorities	
Infrastructure Act 2015 and subsequent Species Control Order (2018)	Allows the Environment Agency to issue voluntary species control agreements and should an agreement of voluntarily control fail to be met, a mandatory control order can then be issued.	-Gives authority to environmental authorities to enforce on landowners to carry out NNIS control operations (Kamigawara et al. 2020)	-Species control orders have limited use, as they are not recommended for species that area already widely established, such as Japanese Knotweed or grey squirrels (DEFRA 2015)
Innvasive Alien Species (Enforcement and Permitting) Order (2019)	This order was released in Britain at the end of 2019. Following on from the legislation set out in the Wildlife and Countryside Act (1981), this order creates stricter regulation surrounding enforcement, with one of the major changes being the prohibition of allowing licences to release NNIS back into the wild	-Creates stricter enforcement regimes surrounding NNIS -Relatively new legislation, so too soon to determine its effectiveness	-Preventing licences to allow release for NNIS can cause backlash from animal rights activists -Relatively new legislation, so too soon to determine its effectiveness
EU Invasive Species Regulation (EC 1143/2014)	The Invasive Alien Species Regulation sets out measures for tackling IAS in EU countries, with a focus on prevention, early detection and rapid eradication and management	-It can help to align GB legislation, where appropriate, with that of animal and plant health to develop consistent and rationalised processes such as border inspection.	-The regulation uses the list of Invasive Alien Species of Union Concern, which is comprised of the major NNIS in Europe. Because it is not focussed on England and Wales, the list may not be as relevant to use. 2. Brexit has created uncertainty in how this law will be impacted in England and Wales.

Table 4: Summary of key NNIS policy, giving a brief description of how each policy works and highlighting their positive and negative attributes.

Policy	Description	Positives	Negatives
Convention on Biological Diversity (CBD)	The CBD uses a three-stage approach to NNIS management: prevention, detection, and control	-The Convention on Biological Diversity (CBD) is the only global legal tool that directly addresses the threats of NNIS, stating that parties must take measures to prevent, control and/or eradicate NNIS. -CBD provides a strong framework for NNIS pathway analysis (Harrower et al. 2017)	-Aichi targets from CBD, include a commitment by 2020 that INNS and their pathways are identified and prioritised, priority species are controlled or eradicated, and pathways are managed to prevent species' introduction and establishment. In 2019 the Government admitted its progress on meeting this target was "insufficient" (JNCC, 2019). -CBD's principles are non-binding, meaning they are optional guidelines for countries with no repercussions for those who do not follow the guidance (Baker et al. 2005)
GB Invasive Non-Native Species Strategy	Originally set up in 2003, and updated in 2008 and most recently in 2015, the GB Non-Native Invasive Species Strategy sets out a framework addressing the threats of NNIS, and key aims to delivering a coordinated and effective approach to NNIS control in England and Wales.	-60 Risk Assessments were created for key NNIS. - Successful efforts were made in eradicating the ruddy duck. -Government campaigns were launched to raise public awareness 'Be Plant Wise' and 'Check Clean Dry'. (Great Britain Non-native Species Secretariat 2015) -Created roles of GB Invasive Non-Native Species Secretariate and GB Programme Board to improve communication with stakeholders to help inform policy in 2005/06 -Created the annual stakeholder forum to allow stakeholders to share concerns and ideas in 2004	-Despite the stated priority given to identifying and preventing threats from new species that could be introduced to GB, it is still the case that resources are more focused on dealing with already established species. -This strategy was intended to be completed and reviewed with new aims every 5 years, meaning an update was due in 2020. However, the government has yet to publish an update to the NNIS Strategy going on from 2020. -Although it helped to create the positions of Species Secretariate and GB Programme Board, these positions have no statutory powers, so are therefore limited to providing communication and guidance but not regulating current law or policy (Great Britain Non-native Species Secretariat 2015)
A green Future: Our 25 Year Plan to Improve the Environment	A foundation for environmental recovery and improvement schemes with the intent of "Adopting a policy of early intervention" and "strengthening biosecurity". The plan of action consists of developing plans to reduce the risk from all high priority pathways for invasive non-native species introduction into England.	-It highlights the need to work more with stakeholders and businesses to develop policies	-Statements surrounding NNIS are vague, with limited figures and detailed goals outlined in the policy.
International Plant Protection Convention	IPPC focuses on the trade of plants; with a strategic framework in place to ensure good plant biosecurity measures are met.		-IPPC guidelines state that a plant only requires quarantine status and preventative measures taken if the plant species is considered to cause detrimental social, economic, or environmental consequences if allowed to spread in the new environment (Baker et al. 2005).

3.7 Systematic Review

Having assessed key law and policy relating to NNIS, the following section will address key areas of concern that were identified through policy documents and a systematic search on Web of Science with the criteria:
(Invasive* OR non-native* OR alien*) AND (Species OR organism* OR animal* OR plant* OR flora* OR fauna*) AND (UK OR United Kingdom OR Britain OR British OR England OR Wales OR English OR Welsh) NOT (Scotland OR Ireland OR Scottish OR Irish OR British Columbia OR British Overseas Territor* OR New England OR New South Wales) AND (law* OR policy OR policies).

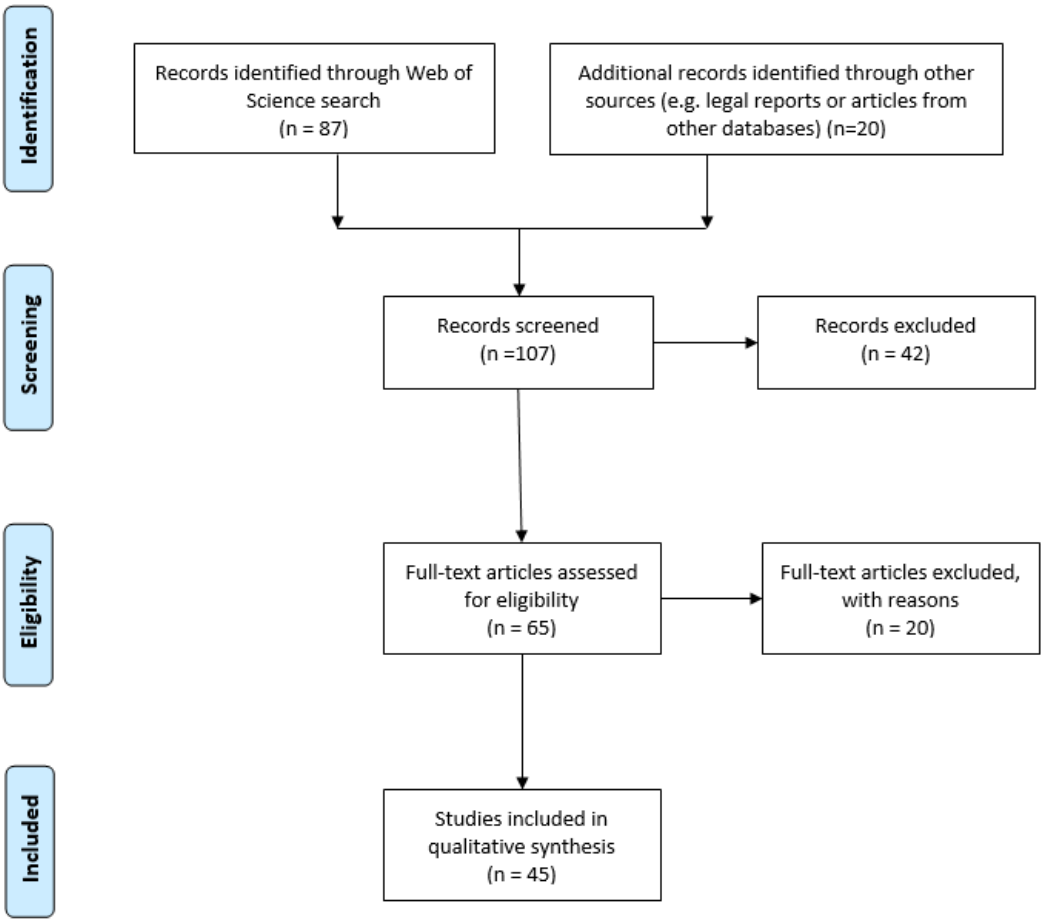


Figure 2: PRISMA flow diagram showing stages of systematic review. Titles and abstracts were assessed at screening stage and excluded or included depending on relevance (see Flow Diagram 1), then full text assessment was completed at eligibility stage to check methods used were comprehensive and full text was still relevant to the topic question, included was then categorised and discussed. Template taken from: http://prisma-statement.org/prismastatement/flowdiagram.aspx

In total, the search for law and policy surrounding NNIS in England and Wales returned 90 results on Web of Science. 42 results were immediately excluded from the study after reading the abstracts either because they were not considered relevant to this study, or due to being unable to access the full texts. It was noted that several studies were literature regarding invasive diseases. Although this is an important issue in England and Wales, diseases are not included in key legislation such as the Wildlife and Countryside Act and the 2019 Enforcement and Permitting Order. This study is focused on flora and fauna therefore, studies on invasive pathogens were excluded. The full texts of the remaining results were then assessed for eligibility dependent on whether the texts addressed the question of whether current law and policy is effective in assisting the control and prevention of NNIS spread in England and Wales, and a further 20 were excluded, leaving 25 results from Web of Science and a further 20 identified from other databases. From the results of the systematic search, the key topic areas were identified and are explored further below.

3.7.1 Responsibilities and Enforcement

According to the Wildlife and Countryside Act (1981) the responsibility of invasive species control falls to the landowners. However, this law states that they must only act to prevent the spread of the species off their land. Case laws have demonstrated that because landowners must only act to prevent the spread of the species off their land, NNIS have been left to grow on sites until enforced against due to species spreading off people's land (Network Rail Infrastructure Ltd v Williams & Anor 2018). This can give species the time to establish and spread through the ecosystem on the private land, but also in some circumstances, the species may spread further (e.g. Japanese Knotweed fragmenting into watercourses and spreading downstream) before any response is taken.

At this point, the cost to control the species will be far greater and often the species will already have caused significant ecological damage to an area. A solution would be legislation offering landowners funding to assist in the removal of the invasive species, provided they take immediate action (DEFRA 2020). Although this would entail an initial governmental cost, it would save in spending for control further down the line due to the proactive approach to tackling the issue at hand. There has been some efforts towards this, with limited government funding being made available to assist in management, where landowners cannot afford the costs, as well as the government focusing on early detection of NNIS to allow for more manageable and affordable control (Kamigawara et al. 2018).

Although the Invasive Alien Species (Enforcement and Permitting) Order (2019) lists stricter regulations, responsibility of enforcement lies with several different authorities being listed (the Secretary of State, Natural England, the Environment Agency, and the Forestry Commission). Although having more enforcement authorities could be more effective in covering more scope, on occasion, it has also led to confusion (e.g. amongst the general public), due to conflicting information given by different agencies (Shannon et al. 2020). The ineffective use of enforcement powers was also explored by Shannon et al. (2020), with results revealing that stakeholders considered enforcement against people allowing the spread NNIS unintentionally (e.g. through poor biosecurity practices by boaters) to be inconsistent and impractical.

Having a consistently funded separate regulatory body specifically focussed on invasive alien species may help develop more focused enforcement of environmental law (DEFRA 2003). Expert enforcement officers with knowledge of identifying invasive alien species within this organisation would be beneficial, as some species (e.g. Giant Hogweed, which looks very similar to native Hogweed) are challenging to identify.

In key legislation (Wildlife and Countryside Act 1981, Invasive Alien Species (Enforcement and Permitting) Order, 2019) Natural England is listed as England's enforcement authority regarding NNIS, however, in Natural England's annual report from April 2018 to March 2019, there was no specific mention of NNIS. Although there is a focus on biodiversity conservation, Natural England has failed to demonstrate any key focus on NNIS control in their annual report.

Although it is evident that Natural England does have on-going NNIS projects, the lack of acknowledgement of them in the annual reports or in their key responsibilities and priorities, suggests that it is not the highest concern on their agenda. To counter a lack of clarity and focus from regulatory bodies, it was recommended that England and Wales created a separate regulatory body, specifically focussed on preventing and controlling NNIS (DEFRA 2003). Subsequent to this, the GB Non-Native Species Secretariate (NNSS) and Programme Board were created in 2005/06 (DEFRA 2015b). Whilst this may have helped in communicating with stakeholders, the NNSS and GB Programme Board hold no enforcement powers or statutory basis and is used more as a coordinator and advisor.

However, government efforts in the field of enforcement have demonstrated clear limitations. For example, research has identified through DNA profiling, that translocations of the North American Grey Squirrel that had previously been thought to be caused by natural expansion, was in fact anthropogenic, meaning that despite being one of the highest profile NNIS in England and Wales, illegal releases of grey squirrels are still very much an issue (Signorile et al. 2016). This indicates that new releases of established and widely recognised NNIS is an issue that needs addressing, highlighting the necessity for better law enforcement as well as addressing the requirement for tools to identify any human-caused releases. Signorile et al. (2016) anticipates that anthropogenic spreading is not limited to just the grey squirrel, and recommends the use of further DNA testing to identify the illegal movement of NNIS and aid enforcement to prevent people from exacerbating their spread in England and Wales.

3.7.2 Prevention and Biosecurity

Prevention of the introduction and establishment of NNIS is widely considered the most effective method of NNIS control (Baker et al. 2005). Therefore, strong, and successful law and policy that addresses the importance of prevention and biosecurity is a crucial step in effectively preventing NNIS spread in England and Wales. However, despite the stated priority given to identifying and preventing threats from new species that could be introduced to England and Wales, it is still the case that resources tend to be more focused on dealing with already established species (DEFRA 2015).

"Biosecurity" can be interpreted a number of different ways. When referring to biosecurity in this study, the term relates to all measures made to prevent the introduction, establishment and dispersal of NNIS across England and Wales. This is inclusive of (but not limited to) legal measures, campaigns and physical activities (e.g. check, clean and dry) that focus on preventing NNIS spread. Biosecurity differs to control, as instead of also including measures for management and eradication of NNIS (e.g. trapping/culling) biosecurity is more focused just on the proactive preventative measures, such as cleaning equipment and border inspections to identify pathways of introduction.

The GB Invasive Non-native Species Strategy (2015) mentioned the need to incorporate better regulations such as border inspections. A study funded by DEFRA states that border inspections are undertaken to reduce the risk of pests and NNIS entering the country, but it also states that there are currently no routine border checks for plants entering from EU member states, meaning NNIS could easily be brought in from European countries (Spence 2020). Furthermore, as highlighted in the House of Commons Environmental Audit Committee (2019), there is still no inspectorate dedicated to NNIS. Border control is essential in preventing the introduction of invasive species before they have a chance to spread and establish. It is more cost effective than controlling species once they have spread into the wild. Therefore, greater focus should be given to biosecurity at British borders.

One of the biggest issues holding back biosecurity practices, such as border inspectorates in England and Wales is the concern of the economic implications it will have towards trade (Maye et al. 2012). However, recent research highlights the extensive costs associated with NNIS spread (Hill et al. 2019). This argument denotes that good biosecurity practice would be economically beneficial and the initial investment in better biosecurity would save the government money in the future.

According to the GB Non-native invasive species strategy (2015), prevention of spread is particularly important in the marine environment where control and eradication are technically challenging. Raising awareness for marine biosecurity practices is therefore integral in preventing spread. One study revealed in a survey of British sailors, that although 90% of respondents were aware of NNIS, over 60% were against the idea of statutory hull cleaning of boats before leaving a marina known to be a NNIS hotspot, mainly due to the costs associated with cleaning (Foster et al. 2016). This indicates that even when there is a general awareness of the threats of marine NNIS, general attitudes towards good biosecurity are still negative, but may be able to be improved if given additional funding to help cover the costs associated with practices such as hull cleaning.

Another study identified that some marinas used a proactive approach to biosecurity, such as making plans to install holding tanks for cleaning hulls. However, the general consensus was that, due to a lack of funding and no legal necessity for marinas to adhere to good biosecurity practices, many marinas showed limited actions towards preventing the spread of marine NNIS. The major barrier preventing good biosecurity in marinas was again identified as the costs associated with biosecurity practices (Vye et al. 2020).

As with marinas, aqua invaders along inland watercourses also demonstrate major concerns when considering biosecurity. These areas face the threat of invasive spread through recreational water sports, such as canoeing and kayaking. One survey revealed that over half of respondents who undertook recreational activities, used their equipment in multiple catchments without undertaking appropriate biosecurity measures (Anderson et al. 2014).

This demonstrates a clear need for better education and stricter biosecurity measures to help reduce the risk of NNIS spread.

The check, clean and dry campaign was launched to increase public awareness and encourage good biosecurity practices. However, the effectiveness of the check, clean and dry campaign in preventing spread has been shown to vary amongst different NNIS. Studies have shown that heating the water for the "clean" process will have varying effectiveness in killing different NNIS (Anderson et al. 2015; Shannon et al. 2018). It was also demonstrated that for some species, the check, clean and dry technique has limited effectiveness. For example, when used on M. aquaticum, it was shown to be only 40% effective (Shannon et al. 2018). Furthermore, it was demonstrated that check clean and dry could be effective, with 100% mortality in signal crayfish, but only when administered for 5 minutes at a temperature of 40°C (Anderson et al. 2015). This highlights the need to assess biosecurity campaigns vigorously, ensuring they are informed by scientific studies to be as effective as possible in preventing NNIS spread before rolling them out nationally.

Research has shown that whilst stakeholders generally agreed on the importance of a need for good biosecurity measures to control NNIS, there was often shortcomings when it came to implementing these practices. The main issues identified were a lack of clear guidance, changing people's attitudes and the costs and time associated with applying good biosecurity practices. It was observed that stakeholders would often only apply good biosecurity towards NNIS that directly impacted their organisations, indicating that a greater sense of responsibility could aid in stakeholders applying better biosecurity (Foster et al. 2016; Suttcliffe et al. 2017). One measure that could be made to improve cooperation from stakeholders, would be to create a biosecurity act, similar to that of Australia, as a legal incentive for people to uphold good biosecurity practices (Shannon et al. 2020).

Even if the best biosecurity practices were implemented, the complete eradication of many NNIS is an unattainable goal. One suggestion is to focus biosecurity efforts on British islands, where it would be more manageable to prevent NNIS spread and conduct effective biosecurity practices to preserve native ecosystems (Stanbury et al. 2017). Eradication of established NNIS has also been shown to be more effective on island ecosystems with much higher success rates in eradication programmes compared to mainland environments (Cassini 2020).

3.7.3 Blacklisting vs Whitelisting

One alternative measure to encompass all potential invasive species threats to the England and Wales, is to incorporate the whitelisting technique adopted by New Zealand. New Zealand is frequently referred to as an exemplary jurisdiction with regards to biosecurity and invasive alien species control biosecurity (Sambrook et al. 2014; House of commons environmental audit committee 2019; Shannon et al. 2020). It operates a strict whitelist; meaning only species that are whitelisted are permitted into the country. This differs from the current blacklisting technique, which instead lists invasive alien species that are prohibited from being released into the wild. The blacklisting approach allows governmental bodies to target specific NNIS to fund management programmes for and prioritise high-risk species. However, blacklists pose the risk that unlisted species will not be considered as important to control or be as carefully regulated and will therefore be able to slip under the

radar and spread with unknown risk to the environment, (Dehnen-Schmutz 2011; Garcia-de-Lomas and Vila 2015).

A whitelist could prevent this threat as the list could be used at borders to prevent all species not listed and not just those on a blacklist. Therefore, having a whitelist sanctioned in England and Wales has the scope for an all-encompassing, far more effective biosecurity (House of commons environmental audit, 2019). It would guarantee that no invasive alien species are disregarded when considering biosecurity, ensuring the best possible preventative action is taken against invasive alien species in the future (Garcia-de-Lomas and Vila 2015). Furthermore, a whitelist could give more clarity to organisations such as the horticultural society as to which species they are able to trade without causing a risk to native populations (Dehnen-Schmutz 2011).

However, there are potential drawbacks to using the whitelisting approach. Whilst an effective whitelisting technique would reduce the risk of spreading new NNIS, it would also prevent the establishment of non-native species that could benefit native ecosystems. Most non-native species that have been introduced into England and Wales have not been invasive, with many creating positive benefits to wildlife (Manchester and Bullock 2001; Gallardo and Aldridge 2014). With the strict measures of the whitelisting technique in place, many potential benefits of new non-native species could be lost.

Furthermore, using blacklisting to focus preventative measures on high priority species has also been demonstrated to be effective in April 2012, when the Asian Hornet Response Plan was finalised and successfully accomplished. This achievement is a unique proactive approach in Europe insofar as it covers a species that is not a statutory pest and is not yet established in England and Wales, with the plan's main objective being to rapidly intercept and prevent the establishment of this species in the GB Invasive Non-native Species Strategy (2015).

If the law were to continue with a blacklist, one improvement that could be made would be to create a "grey" list of species that have the potential to be invasive, which would cover a wider range of NNIS, reducing the potential for species of an unknown threat to establish (Garcia-de-Lomas and Vila 2015).

3.7.4 Risk Assessment

Whether using a blacklist or whitelist, it is important to undertake risk assessments to establish whether non-native species have the potential to become invasive if allowed to establish in England and Wales (Garcia-de-Lomas and Vila 2015). These risk assessments must be undertaking using a clear, systematic method with solid scientific backing to ensure they are reliable.

Risk assessments were initially recommended by DEFRA (2003). However, initial reviews of the risk assessments in place discovered a low level of accuracy with concerns for the methods used being unsystematic, determining that research and development of risk assessments was needed involving more NNIS testing (Booy et al. 2006; Keller 2011; Carboneras et al. 2017).

Since then, there have been more research projects into the best practices for assessing the risk of NNIS. This research should be incorporated to ensure that NNIS are scientifically evaluated with ecological impacts being considered when assessing how great a threat different species is.

Predictive approaches are one such method that could be used to assess risks of different NNIS. One such method is Comparative Functional Response (CFR), which compared consumption rates between a NNIS and similar native species. The CFR is determined by replicating natural habitats in a captive or semi-captive environment and testing different factors such as competition amongst native species and NNIS to assess the risk of the NNIS establishing and spreading in such an environment (Britton 2018). This method can be a useful tool in establishing the impact NNIS have, and has frequently revealed that the feeding rates of NNIS are higher than those of comparable native species (Dick et al. 2017; Britton et al. 2019).

To rely solely on ex-situ experiments to predict NNIS risk would disregard the differences that may occur between captive environments simulating the wild and wild habitats, such as more intense competition than would naturally occur in the wild (Britton 2018). Furthermore, ex-situ environments do not account for the complexity of natural systems, where many more variables are in play, which highlights the difficulties associated with successfully assessing the risks of NNIS (Britton et al. 2019). However, CFR could be used in a standardized way across all taxa to help risk assess non-native species and predict their invasiveness (particularly their impact on native competitors and prey) when released into a new environment (Dick et al. 2017).

Another study used Relative Impact Potential to focus on ecological impacts of NNIS. This method uses several factors to calculate the anticipated impact of a NNIS. These include the average lifespan of the NNIS, the estimated maximum feeding rate, known as the functional response (FR), and the fecundity (reproductive output calculated from clutch size and frequency). Developing from previous studies, this study also included attack rates to account for different resource availabilities changing the impacts of a NNIS as well as pet propagule pressure, which considers the likelihood of pets becoming unwanted and being released, contributing to the distribution of that species (Dickey et al. 2018).

Including ecological impact is important, as ecosystem services and the natural capital can be majorly affected by NNIS spread. Using the research from Relative Impact Potential alongside economic and social studies could certify a sustainable approach to NNIS control, ensuring that all the impacts of NNIS are considered when prioritising control programmes (Dickey et al. 2018).

Horizon-scanning is also an important measure in proactive response to NNIS and preventing their introduction and spread in England and Wales. Horizon-scanning involves assessing future potential threats of NNIS and was a key element of the 2008 GB Invasive Non-native Species Strategy (Thomas 2011). The methods for horizon scanning consist of consulting expert groups in the field of NNIS through several stages to establish a score associated with the risk factor of each NNIS (Roy et al. 2014). In order to make horizon scanning easier and to establish pathways of introduction of NNIS, the European Alien Species Information Network (EASIN) was developed to facilitate easy access to all jurisdictions across Europe and help share knowledge to prevent NNIS spread (Pergl et al. 2020).

The Non-Native Risk Management (NNRM) scheme used this process to highlight the need for prioritisation of NNIS control, with considerations for feasibility and practicality of eradication/effective control and the likelihood of re-invasion also being taken into account. This technique involves surveying experts from varied backgrounds to establish risk assessment scores for different NNIS (Booy et al. 2017). Although there is a level of bias in this technique, workshopping, discussions, and reviews to challenge the results helped to minimise this, making NNRM a potentially useful tool in undertaking risk management of NNIS and prioritising species for control efforts.

Sharing knowledge across different jurisdiction is also an important factor in creating informed risk assessments. The use of the European-wide information portal, DAISIE should be included to obtain information surrounding NNIS and create more comprehensive risk assessments (Collier 2018).

As well as species risk assessment, predictions of species distribution can be a useful tool in determining the best actions going forward to prevent NNIS spread (Jones et al. 2013). Therefore, by understanding both the threats non-native species pose and the likelihood of them establishing and spreading in different areas across England and Wales, species can be prioritised accordingly and efforts into prevention and management can be more effective.

3.7.5 Distribution

For species that have already been established in England and Wales, a key tool in effective management is investigating the distribution of species. If predictions can be made as to where NNIS will establish and spread, a more proactive approach to management can be taken in areas of higher risk to invasion and the results of the predictions can be used to inform policy (Jones et al. 2013).

Ascertaining the distribution of NNIS can be a costly and time-consuming job. However, one study discovered that data collected for Marine Conservation Zones (MCZs) could be used to detect NNIS in British waters (Whomersley et al. 2015). This idea could be an effective method of saving time and resources by using current ecological databases where possible to help in determining the distribution of NNIS, particularly in marine environments where protocols for recording NNIS are unclear (Whomersley et al. 2015).

Species Distribution Models (SDMs) are often used to understand the distribution of NNIS, using factors such as climate, land use and habitat suitability to predict hotspots for NNIS spread (Gallardo et al. 2015; Polaina et al. 2020). They can also be used for ongoing management programmes to predict the most effective methods of control for an area (Jones et al. 2017). This can be a useful tool in forward planning and using optimum strategies when undertaking NNIS management and should be an important tool to inform policy.

It is important to note that there will always be a level of uncertainty with SDMs, as they often assume a fixed habitat structure and makes estimates regarding different variables. However, information from them can still be a useful tool to aid in creating NNIS management strategies (Jones et al. 2017). It is also important to understand and include all factors affecting distribution to make an SDM as accurate as possible, however human

activities that influence NNIS distribution have often not included these factors when designing SDMs (Gallardo et al. 2015). For example, one study found that the construction of offshore wind farms can create a habitat for marine NNIS, and the more compact the turbines, the greater the risk of NNIS establishment (Börger et al. 2014).

One potentially beneficial route to determine the spread of different NNIS is to use the public to aid in sightings of NNIS. The "Plant Tracker App" is one method for this, an app developed by the Environment Agency that uses data collected by the general public to establish the distribution of different non-native invasive plants (National Biodiversity Network Trust 2012). Other apps such as the RINSE That's "Invasive!" and KORINA apps have also been designed to encourage the public to participate in identifying and logging NNIS across Europe. These apps have not only been useful in locating NNIS spread, with records adding to and complementing professional monitoring schemes, but they have also encouraged the public to get involved in NNIS control projects and raised general awareness of NNIS (Adriaens et al. 2015). However, limitations in this method may occur due to the public only using the apps infrequently, so distribution data collected may be inadequate if public participation is not consistent (Adriaens et al. 2015).

3.7.6 Education and Public Awareness

Although attitudes towards NNIS control have been shown to be positive for some cases, public awareness of the issues caused by NNIS is low (Eriksson et al. 2018). Studies show that educating the public on the negative impacts associated with NNIS increases support for control projects (Novoa et al. 2017; Eriksson et al. 2018). Therefore, to effectively manage NNIS in the future, more efforts should be made to increase public awareness and therefore gain their support in preventing NNIS spread.

Another issue with a lack of public awareness surrounding NNIS is identification. One study in Cornwall determined that less than 20% of the population were able to identify Japanese Knotweed, one of the highest profile non-native invasive plants in England and Wales (Robinson et al. 2016). This is a great concern, as organisations such as the EA use public participation to help identify locations where NNIS are present (plant-tracker, aqua-invaders). If the public cannot identify NNIS, they will not be able to report them and assist the authorities in finding and tackling problem areas. One way to help educate the public and counter this issue would be to identify the demographics with the least knowledge regarding NNIS and target them to improve awareness (Robinson et al. 2016).

Increasing public awareness can lead to public participation in preventing NNIS spread in England and Wales. Due to the speed at which many NNIS can spread, public participation is often key to achieving successful control strategies (Tattoni et al. 2006). As well as identifying and reporting areas containing NNIS, the public can help in several other ways including participation surveys, practising good biosecurity and even, in some cases, volunteering to assist in removal projects (e.g. Himalayan "Balsam Bashing"). Volunteering is a key contributor to achieving NNIS management due to limitations in funding and resources and can be a useful tool in engaging citizens in nature conservation and educating them on NNIS (Pagès et al. 2019). Public awareness is also important to encourage the public to adhere to the law and not unintentionally aid the spread of NNIS further.

The threat of NNIS as perceived by the public does not always correlate to the actual ecological risks of different species (Robinson et al. 2017). This means that attitudes towards different NNIS do not always reflect how detrimental those species are to social, economic and/or environmental factors. This may lead to conflicts of interest when focussing on tackling NNIS, as the lack of understanding may prevent public support in control projects or changes to law and policy surrounding NNIS.

However, public opinion can also help to guide in decision-making regarding NNIS. Public perceptions can help highlight areas of the most significant concern for specific NNIS in England and Wales. For example, a study on Japanese Knotweed in Cornwall indicated that the primary motivation for controlling Japanese Knotweed on private land would be to prevent it spreading onto adjacent land (Robinson et al. 2017). This indicates that respondents are aware of the law (Wildlife and Countryside Act 1981) and that in this instance, legislation was the most effective tool in motivating the public to control NNIS on their land. This example highlights the importance of law and policy in tackling NNIS, iterating why it is so essential that legislation is as effective as possible to best prevent NNIS spread.

However, often conflicts of interest from the public lead to problems regarding public support for NNIS management and control projects. Professionals tend to have more extreme views regarding NNIS impacts and methods of control. Studies also showed that the public were more averse to highly abundant, damaging, or unattractive NNIS (Fischer et al. 2014).

One study interviewed the British public in on their opinions of non-native species in parks and gardens. The results showed that the majority of respondents would rather see more non-native species, with only 20% of participants stating that only native plants should be used. These results suggest that despite law and policy having a very negative outlook on non-native species, public perception is much more open to the introduction of new species (Hoyle et al. 2017). However, this study investigated the general public opinions. Therefore, their opinions of non-native species may be more positive, as they may not be aware of the threat of invasion by non-native species and the negative impacts associated with their spread. Furthermore, another study surveying respondents on marine offshore windfarms found that 61.8% of respondents felt that measures should be put in place to prevent further introduction of NNIS, with a further 22.4% stating they needed more information (Börger et al. 2014). Most respondents for this study were therefore against NNIS establishment or wanting to know more in order to make an informed decision. It is important to note that these two studies were undertaken for very different environments (offshore wind farms and public gardens), which is likely to have had an influence on public perceptions. Furthermore, species from different environments demonstrate different levels of knowledge, for example, knowledge surrounding terrestrial NNIS tends to be far greater than for aquatic species (Gozlan et al. 2013). This highlights the need to consider the environment in which different NNIS establish when considering public attitudes towards and their understanding of NNIS.

3.7.8 Ethical Concerns

In certain cases, particularly for mammalian NNIS, conflicts arise from the public regarding the ethics of NNIS control methods (e.g. culling). As identified in the case of the North American Grey Squirrel, particularly after the new Invasive Alien Species (Enforcement and Permitting) Order (2019) prohibited Natural England from issuing any more release permits for NNIS, ethical issues can often arise. Ethical concerns can stem from a number of issues including failed eradication programmes resulting in species mortalities with little ecological benefits, non-target species being impacted by control measures and inhumane methods of control such as toxins (Cowan and Warburton 2011).

Concerns from the public regarding NNIS control often arise from moralistic values for animal species in all environments, which can be difficult to overcome when attempting to gain public support for control programmes. This is less of an issue for plant species but can still be problematic in rural areas (Novoa et al. 2017). Another study also found that public perceptions of NNIS were influenced by the "attractiveness" of a species (Fischer et al. 2014). This indicates that control programmes for different taxonomic groups are likely to receive different responses from the public, a factor which should be considered when planning NNIS control.

Difficulties can often arise in the practicality of NNIS control programmes. For species that are widely established across England and Wales (e.g. the grey squirrel), it is often difficult to prove that eradication programmes will be effective in removing the issues caused by the NNIS in question (Cassini 2020). It has been noted, however, that the most successful eradication programmes have occurred on islands (Cassini 2020), therefore successful eradication may be more attainable in England and Wales. To help avoid the issues of ethical concerns, it is advised that scientific evidence is provided to prove the benefits of culling programmes and justify lethal methods (Reynolds et al. 2013; DEFRA 2020).

3.7.9 Arguments Against NNIS Management

Although most studies recognise the detrimental impacts of NNIS and focus on the need to control and manage their spread throughout England and Wales, the search did return a few studies that had slightly different viewpoints. One study investigated not just the negative impacts, but also highlights the benefits that NNIS can bring to ecosystem services, stating that analysing both the pros and cons can lead to a more fair and feasible management than attempting eradication programmes (Martinez-Cillero et al. 2019). This study states that accepting some NNIS and allowing nature to change may be a better and more practical solution.

Furthermore, as aforementioned when investigating public perceptions, findings revealed that most of the respondents would welcome the spread of non-native plant species and are accepting of the changes in biodiversity that they would bring (Hoyle et al. 2017). However, the study also stated that certain respondents (particularly those with biocentric values and more awareness of policy) had concerns regarding the potential invasiveness of non-native species being allowed to establish and the impact on native species. This demonstrates that those with a more invested interest and more awareness of NNIS are more adverse to the idea of non-native introductions, indicating that if the public were more aware, they may be

less supportive of allowing their spread. Despite this, the study concluded by stating the inevitability of non-native invasions, concluding that policy should reflect on the public opinions in order to achieve a sustainable future. Although these points do not detract from the negative threats associated with NNIS, they do highlight the need to consider all perspectives, include public opinions, and ensure NNIS management programmes will bring long-term benefits to the environment (Hoyle et al. 2017; DEFRA 2020).

3.7.10 Climate Change

The impacts of anthropogenic climate change and how they affect ecosystems in England and Wales are a key factor in assessing the management of NNIS going forwards, as global warming is a key influencer in NNIS establishment (Huang et al. 2011). The global spread of NNIS is limited by climates, with 42% of species distribution being reliant on temperature (Gallardo et al. 2015) This suggests that some NNIS will become more capable of establishing in England and Wales given recent warmer environments caused by climate change. Another major concern with climate change is that previously non-invasive non-native species could potentially become invasive if climatic conditions become more suited to them (Manchester and Bullock 2001; Fobert et al. 2012; Hulme 2016).

The extent to which climate change impacts upon NNIS establishment and spread is disputed, however. A study on non-native birds assessed whether climate change would exacerbate NNIS, by creating more climatically suitable environments for these species. However, the research concluded that there was little evidence to suggest this was the case, as the species were shown to adapt to new climates and would spread regardless of climate changes (Border et al. 2018). Another study that investigated the impacts of anthropogenic climate change and land use and land cover (LULC) on NNIS distribution (namely Rhodedendron Ponticum) determined that climate change did influence NNIS spread, however LULC had a greater impact on species distribution and advised that using models combining the two factors should be used to forecast NNIS distribution (Manzoor et al. 2021).

Determining the influence of climate change on NNIS in England and Wales is difficult however, and it has been suggested that other factors such as globalisation and land-use are more likely to influence the spread of NNIS (Hulme 2016).

It is also argued that non-native species should not be vilified so quickly, as climate change has had a profound impact on biodiversity and species distribution, therefore it would be impossible to return wildlife in England and Wales to the state it was in historically (Hoyle et al. 2017). One study even argues that non-native species (such as exotic tree species) should be allowed to establish to replace species that are struggling due to factors such as climate change (Ennos et al. 2019). Further research into the impact of anthropogenic climate change has on ecosystems in England and Wales and how this will affect efforts to control NNIS spread is recommended.

3.8 Summary

Table 5: A summary of the key findings from the systematic review and subsequent recommendations to improve legislation and management efforts of NNIS in England and Wales

	Positives	Negatives	Recommendations
Responsibilities and Enforcement	1. British legislation clearly identifies the landowner to be responsible for NNIS on their land 2. Some limited funding has been provided by the government to assist in NNIS control	1. Landowners may not control NNIS on their land unless enforces against, giving time for species to spread further. 2. Multiple enforcement authorities giving conflicting advice can cause confusion 3. Inadequate enforcement has resulted in a failure to stop new introductions of high profile NNIS	1. Invest more money into assisting landowners in controlling NNIS on their land to promote proactive responses to management 2. Create a separate, consistently funded enforcement body, specifically focused on NNIS 3. If a separate NNIS enforcement body is not possible, encourage good communication between current enforcement authorities to ensure a coordinated approach to NNIS management and enforcement efforts
Prevention and Biosecurity	1. A lot of British policy highlights biosecurity as the priority concern in achieving NNIS control. 2. The Government have implemented campaigns, such as "check, clean and dry" to promote good biosecurity practices	1. England and Wales still has no biosecurity inspectorate dedicated to NNIS at our borders 2. The uptake of good biosecurity practices is hindered by public education and attitudes	1. Invest in a NNIS biosecurity inspectorate to strengthen borders against NNIS 2. Consider creating a biosecurity act (as seen in Australia) as a legal incentive for people to undertake good biosecurity practices 3. Help fund good biosecurity protocol by providing resources and supporting campaigns such as "check, clean and dry"
Adopting the Whitelisting Approach	1. Whitelisting is all encompassing, reducing the risk of unlisted NNIS from being "missed" and spreading in England and Wales	1. Blacklisting can help provide a focus for priority NNIS to control and prevent from spreading 2. Not all non-native species are detrimental. Whitelisting could prevent beneficial non-native species from being allowed to establish in England and Wales	1. Further research is required to ascertain whether blacklisting or whitelisting is the best approach in England and Wales 2. England and Wales could adopt a "greylist" for species that have the potential to cause detrimental impacts and require risk assessments
Risk Assessment	1. Risk assessments are a useful tool in establishing the potential threat of non-native species in England and Wales and informing law and policy accordingly	1. Risk assessments can be limited if certain factors (e.g. ecological impacts) are not considered	1. Ensure risk assessments are comprehensive and consider all factors when assessing NNIS 2. Share in knowledge from other jurisdictions by using databases such as DAISIE to better understand risks posed by NNIS
Distribution	1. Species distribution models (SDMs) can help identify hotspots and predict the spread of NNIS in England and Wales	1. SDMs always demonstrate a level of uncertainty in their results	1. Use distribution data from other areas of research where possible to assist in creating SDMS to save time and resources 2. Ensure SDMs are as detailed and thorough as possible, considering all variables to minimise uncertainty in results
Education and Public Awareness	1. Increased public awareness can encourage volunteering for control works 2. With more public aware of NNIS, more people are likely to report sightings of NNIS, helping authorities better understand NNIS distribution 3. Public education and awareness of the threats of NNIS usually increases support of control programmes	1. Current public education surrounding NNIS is poor, with very few people knowing and understanding the threats of NNIS 2. Public attitudes towards NNIS management can be negative	1. Invest more into educating the public of the threats and detrimental impacts of NNIS in England and Wales 2. Include the public where possible in monitoring and controlling NNIS, as public participation will gain public support, improve education and save on resources

Ethical Concerns and Arguments Against Control	1. The public demonstrate their concern for wildlife and nature in England and Wales	1. Public concerns can lead to conflict and backlash against management of NNIS that involves culling 2. Many people would welcome the introductions of new non-native species 3. It is argued that some large-scale eradication programmes are ineffective and a waste of resources	1. Ensure to always provide transparent and significant proof to the public that any culling programmes are necessary and will provide substantial benefits to the environment 2. Communicate with public, listening to their concerns and providing scientifically backed responses to prove that control is the best option and management programmes have been strategised to achieve effective results
Climate Change	1. Climate change could hinder NNIS spread, and has prevented the spread of NNIS in many areas globally	1. Anthropogenic climate change could alter the climate conditions to make them more suitable for NNIS to establish 2. Some studies argue that climate change has little bearing on NNIS spread, indicating that species will disperse and adapt to climatic changes	1. Continuing efforts to reduce global warming may also help prevent further NNIS spread 2. Further research to establish the extent to which climate change influences NNIS spread is recommended

4 Case Study Reviews

4.1 Introduction to Section

An analysis of select case study species was used to help critically evaluate the law and policy surrounding invasive species control and prevention in England and Wales. Candidate species suitable for this study were required to have many studies of their invasive impacts and control methods, as well as ideally being incorporated into publications that addressed British law and policy for NNIS excluding the separate legislation used in Scotland. Using numerical analysis was deemed suitable to select these species, as the first task was to identify the quantities of relevant research available for different NNIS.

4.2 Species Selection Review

In order to select case study species, it was first essential to select a suitable list of the NNIS within England and Wales, as different authorities have different classifications of non-native invasive species (Wildlife and Countryside Act 1981, Regulation (EU) No 1143/2014, NNSS 2018). However, as a key law with a focus in England and Wales, the most recently revised version of Schedule 9 of the Wildlife and Countryside Act (1981) was chosen for this study.

From this list, case study species of high profile had to be selected, to ensure sufficient research would be available about them. Furthermore, higher-profile NNIS were considered more likely to have a substantial impact, therefore would be better suited when assessing the law's effectiveness. The aim of the selection review therefore, was to identify and select case study NNIS that were frequently mentioned and researched in literature, due to having significant detrimental impacts on the environment. This meant that the research criterion was reasonably broad. A search of literature focussed on NNIS from the appropriate timeframe and within the correct location (England and Wales) was important. It was decided to include all studies from 1981 onwards, as this was after the implementation of Schedule 9 of the Wildlife and Countryside Act.

A method was used to assess the extent to which different NNIS have been researched to choose suitable candidates as the case study examples. This analysis involved searches made on Scopus and Web of Science for all NNIS in Schedule 9 of the Wildlife and Countryside Act. For these searches, the common and scientific names were used (e.g. Bitterling AND Rhodeus sericeus) followed by the search UK OR United Kingdom OR Britain OR British OR England OR Wales OR English OR Welsh AND NOT
Scotland OR Ireland OR Scottish OR Irish OR British Columbia OR British Overseas Territor* OR New England OR New South Wales. Each search was filtered to the English language. To incorporate research from a wider range of sources, a search was also conducted on Google Scholar, as this search site encompasses a wide range of papers from different databases. However, as this site does not allow for such complex Boolean searches, only the scientific names were used in these searches. This search was therefore less accurate, but the results from Google scholar could still be effectively used as a comparison tool to determine whether the more focussed results from Web of Science and Scopus were likely to be demonstrative of the trends seen in literature within the field.

Selection review results:

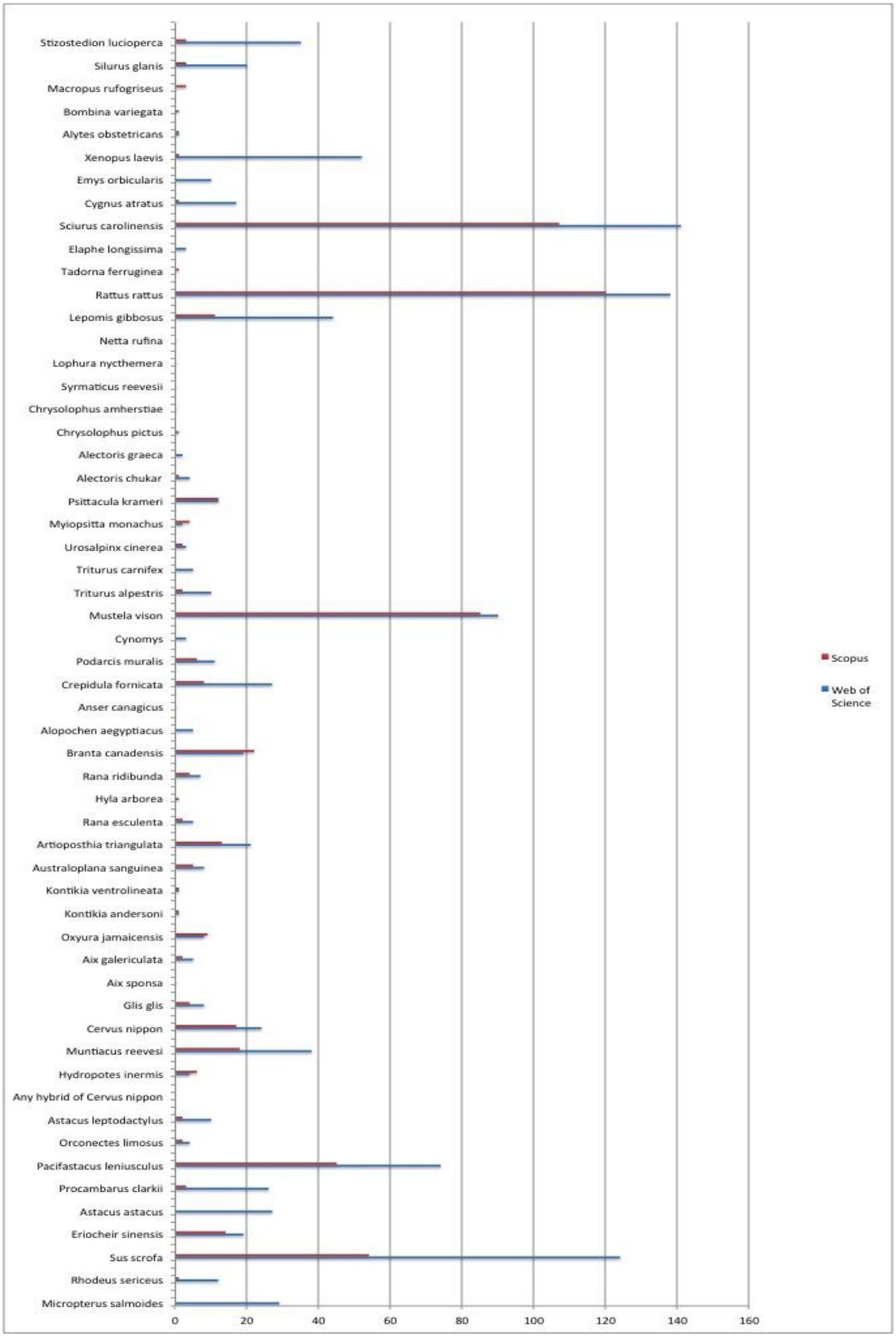


Figure 3: Search results of Schedule 9 Animals from Web of Science and Scopus

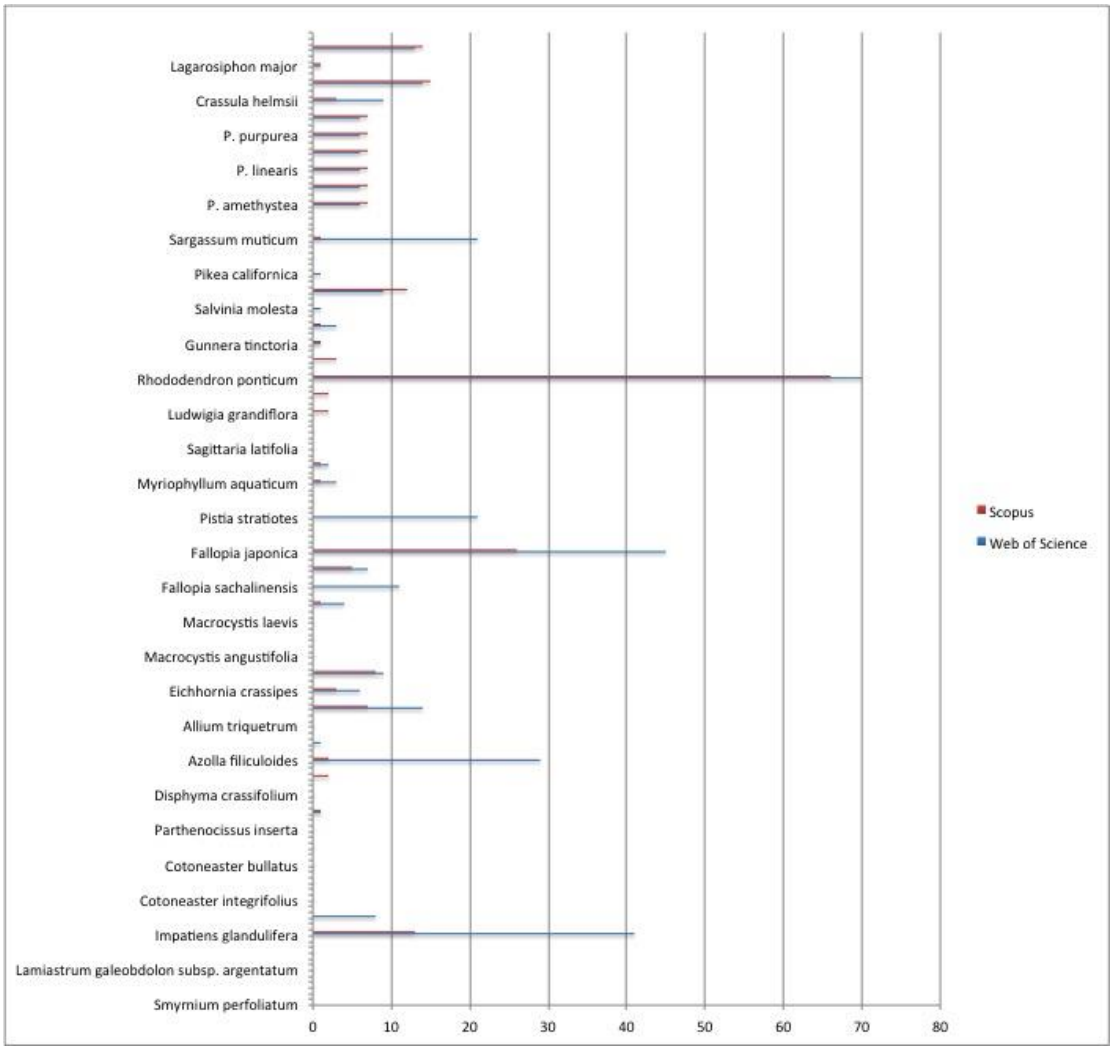


Figure 4: Search results of Schedule 9 Plants from Web of Science and Scopus

The species that returned the most results (i.e. those with results higher than or equal to the mean of all NNIS in the list from Web of Science, Scopus and Google Scholar) were identified for further testing. The initial analysis identified 17 species with substantially higher profiles (more results), 9 of which were non-native invasive plants and 8 were animals (See table 1). As well as ensuring studies were relevant to England and Wales, it was important to ensure that these results included research surrounding NNIS law and policy. Therefore, a second search was taken to ensure that there was relevant literature on law and policy for the species as well. For this step, the terms law* OR legislation OR policy OR policies were added to the search to further narrow down the number of suitable candidate species. Furthermore, the search terms Invasive* OR non-native* OR alien* were also searched along with the species, to ensure that studies showed a focus to the invasiveness of the species within the given location and timeframe. From these searches, five suitable species candidates were identified, three animal (signal crayfish, American Mink and grey squirrel) and two plant species (rhododendron and Japanese Knotweed).

Table 6: Search results for volume of key literature and law literature identified for high profile NNIS in England and Wales

Species (Animals)		**Search Criteria**	**Web of Science**	**Scopus**
			Search Results	Search Results
Crayfish, Signal	*Pacifastacus leniusculus*	law* OR legislation OR policy OR policies	6	45
		Invasive* OR non-native* OR alien*	51	45
Deer, Muntjac	*Muntiacus reevesi*	law* OR legislation OR policy OR policies	1	23
		Invasive* OR non-native* OR alien*	6	18
Deer, Sika	*Cervus nippon*	law* OR legislation OR policy OR policies	0	19
		Invasive* OR non-native* OR alien*	4	17
Goose, Canada	*Branta canadensis*	law* OR legislation OR policy OR policies	3	22
		Invasive* OR non-native* OR alien*		
Mink, American	*Mustela vison*	law* OR legislation OR policy OR policies	9	64
		Invasive* OR non-native* OR alien*	34	64
Pumpkinseed (otherwise known as Sun-fish or Pond-perch)	*Lepomis gibbosus*	law* OR legislation OR policy OR policies	1	11
		Invasive* OR non-native* OR alien*	2	21
Rat, Black	*Rattus rattus*	law* OR legislation OR policy OR policies	4	7
		Invasive* OR non-native* OR alien*	12	113
Squirrel, Grey	*Sciurus carolinensis*	law* OR legislation OR policy OR policies	6	107
		Invasive* OR non-native* OR alien*	39	107

Species (Plants)				
Balsam, Himalayan	*Impatiens glandulifera*	law* OR legislation OR policy OR policies	2	11
		Invasive* OR non-native* OR alien*	35	13
Fern, Water	*Azolla filiculoides*	law* OR legislation OR policy OR policies	1	3
		Invasive* OR non-native* OR alien*	3	3
Hogweed, Giant	*Heracleum mantegazzianum*	law* OR legislation OR policy OR policies	1	6
		Invasive* OR non-native* OR alien*	10	6
Kelp, Giant	*Macrocystis pyrifera*	law* OR legislation OR policy OR policies	0	3
		Invasive* OR non-native* OR alien*	0	5
Knotweed, Japanese	*Fallopia japonica*	law* OR legislation OR policy OR policies	5	23
		Invasive* OR non-native* OR alien*	35	26
Rhododendron	*Rhododendron ponticum*	law* OR legislation OR policy OR policies	1	66
		Invasive* OR non-native* OR alien*	11	35
Seafingers, Green	*Codium fragile*	law* OR legislation OR policy OR policies	0	12
		Invasive* OR non-native* OR alien*	2	0
Wakame	*Undaria pinnatifida*	law* OR legislation OR policy OR policies	1	15
		Invasive* OR non-native* OR alien*	12	15
Waterweeds	*All species of the genus Elodea.*	law* OR legislation OR policy OR policies	1	14
		Invasive* OR non-native* OR alien*	2	14

As well as having appropriate levels of relevant research, it was considered essential for this study to choose case study species of varying taxonomy, with different habitats and covering a variety of social, environmental, and economic impacts. Therefore, three species were chosen that had these varying characteristics:

Although Rhododendron returned a similar number of results in the searches, Japanese Knotweed was chosen instead as the case study plant species, as it is not only detrimental to native ecology, but is also widely known for causing infrastructural damage, as well as having negative economic impacts for landowners. Because human impacts we re important areas to investigate for this study, Japanese Knotweed was therefore chosen.
The initial search for Japanese Knotweed returned 1121 results (71 refined results), 45 from Web of Science, 26 from Scopus and 1050 from Google Scholar. After adding the term Invasive* OR non-native* OR alien* to the search criteria, there were 61 results, 35 from Web of Science and 26 from Scopus. Including the search terms law* OR legislation OR policy OR policies into the criteria reduced the results to 28 in total , 5 from Web of Science and 23 from Scopus.

As the highest profile invertebrate species and only aquatic species to be shortlisted, the North American signal crayfish was also chosen as one of the case study species. The initial search for signal crayfish returned 1349 results (119 refined results), 74 from Web of Science, 45 from Scopus and 1230 from Google Scholar. After adding the term Invasive* OR non-native* OR alien* to the search criteria, there were 96 results, 51 from Web of Science and 45 from Scopus. Including the search terms law* OR legislation OR policy OR policies into the criteria reduced the results to 51 in total, 6 from Web of Science and 45 from Scopus.

As the species that returned the highest number of results overall, the North American Grey Squirrel was chosen as a vertebrate mammal species that is prolific in a number of habitats, but most notably woodland and garden environments.
The initial search for grey squirrel returned 2428 results (248 refined results), 141 from Web of Science, 107 from Scopus and 2180 from Google Scholar. After adding the term Invasive* OR non-native* OR alien* to the search criteria, there were 146 results, 39 from Web of Science and 107 from Scopus. Including the search terms law* OR legislation OR policy OR policies into the criteria reduced the results to 113 in total, 6 from Web of Science and 107 from Scopus.

Inclusion criteria

- Impacts of chosen species
- Current control methods of chosen species
- Law and policy relating to chosen species

Exclusion criteria

- Studies of chosen species in their native range
- Studies of chosen species as invasive threats outside of chosen location
- Studies of chosen species not relating to their invasiveness or spread

For results returned in this search, they were also checked using Flow Diagram 1, with the titles and abstracts being screened to identify relevant studies.

4.3 North American Grey Squirrel

The North American grey squirrel *(Sciurus carolinensis* Gmelin) is a widely known non-native invasive species in England and Wales.

From categorising results from the systematically approached review, the key topics returned for grey squirrel searches on Web of Science were ethics (61), red squirrel habitats (594), management and control methods (35), impacts (24) and distribution (17). The majority of results focused on the impacts of greys on red squirrels, particularly regarding diseases. The majority of literature focussed on environmental impacts of the grey squirrel rather than economic or social factors. With regards to management, physical methods (e.g. trapping) returned more research results than biological or chemical, although several papers did mention the potential use of predators to control grey squirrels. Only seven papers discussed law and policy, with only 4 focussing on it in the study. Other papers covered various areas that were not considered relevant to the study and were therefore excluded.

Grey squirrels are known to have a negative impact upon native species, acting as a competitor to native red squirrels and causing major issues for commercial foresters with one issue frequently mentioned in research being their tendency to strip bark from trees, a behaviour generally acknowledged to occur for the squirrels to intake the stores of calcium from under the bark (Mayle et al. 2009, Mountford 2006, Rayden 2004).

Grey squirrels also thrive in urban areas, with bird feeders benefiting grey squirrels, as research shows unforeseen detriment to breeding birds building nests near feeder in urban areas, due to being at greater risk of nest predation from grey squirrels (Hanmer et al. 2016).

Although there is an abundance of research for the species as a whole, several areas have seen a greater focus, with systematic searches of Web of Science and Scopus revealing that the majority of studies within England and Wales focussed on grey and red squirrel interactions and diseases carried and spread by grey squirrels. Many papers on disease investigated squirrel pox, leprosy, and adenovirus (Macpherson et al. 2015; Everest et al. 2019; Schilling et al. 2019).

Their impact has had hugely detrimental consequences for red squirrel populations since the grey squirrel was introduced to the UK. Therefore, it is of no surprise that the search returned extensive results for literature addressing the impacts of grey squirrels on the reds.

The most common method for control of grey squirrel invasions is through culling. Unfortunately, culling success is limited, with few projects being able to totally eradicate the species from areas. This can be problematic when considering the native red squirrel populations, as the presence of grey squirrels in an area increases competition, creates the risk of disease and leads to increased psychological stress in red squirrels (Santicchia et al. 2018). Furthermore, some research has shown that the presence or absence of grey squirrels in a community is far more important than their population density, and that a decreased population density does not significantly lessen the negative impact on red squirrels (Chantrey et al. 2014).

However, other research suggested that that culling of grey squirrels can significantly reduce the likelihood of a population having detrimental impacts on red squirrels through disease

as well as competition (Schuchert et al. 2014). This therefore would suggest that culling of grey squirrels can still be an important factor in maintaining native biodiversity and protecting red squirrel populations. However, the factors accounting for other successful control are otherwise not clear. Management of grey squirrels in England and Wales is predominantly through poisoning, achieved through warfarin dispensed in hoppers (The Grey Squirrels Warfarin Order 1973). However, this strategy is flawed due to the risk it poses to non-target species, specifically the red squirrel. Subsequently, it cannot be implemented if the risk of impacting red squirrel populations is present due to the prohibition of the poisoning of the red squirrel under the Wildlife and Countryside Act (Crowley et al. 2017). Therefore the implementation of this method is limited, as it is subject to specific conditions in order for it to be carried out legally.

Squirrel pox is a disease caused by the *Squirrelpox virus,* which grey squirrels are immune to, but can carry asymptomatically, spreading amongst red squirrel populations, and subsequently killing them (McGowan et al. 2014). Research has identified that the morphology of the squirrel and parasitism can impact how susceptible grey squirrels are to carry pox, meaning some populations are therefore more likely to contract the disease and spread it to reds (McGowan et al. 2014). Consequently, sampling and research into which populations of grey squirrels within England and Wales are the most likely to spread squirrel pox, and targeting those populations first, could aid in red squirrel conservation.

However, not all research papers found negative effects of grey squirrels in England and Wales. Research has demonstrated that there are arguably some benefits to the presence of grey squirrels, such as them being one of the leading dispersers for hazelnuts (Laborde and Thompson 2009). Another benefit of the grey squirrels was the social aspect, particularly within urban areas, as grey squirrels create a bridge between city life and nature, often being the only exposure to wildlife that people living in urban areas have (Martinez-Cillero et al. 2019).

Other studies also mentioned public awareness, highlighting the issues of morality and public disagreement with the control of grey squirrels through culling (Dunn et al. 2018). A study that investigated the public perception of threats posed by NNIS found that 44% of respondents recognised grey squirrel as being a high ecological risk, indicating that public education surrounding the detrimental impacts of grey squirrels could be greatly improved (Gozlan et al. 2013). Raising public awareness of the negative impacts grey squirrels have on native ecology, such as the impacts on native nesting birds through predation, most notably common blackbird and the positive relationship between egg failure and grey squirrel abundance, may assist in decreasing these conflicts of interest (Newson et al. 2009).

However, research has been undertaken investigating alternative methods of control to culling: A spatial study on the largest remaining red squirrel population in England showed some success in grey squirrel control by felling the trees more appealing to grey squirrels and encouraging coniferous tree species that are more suited to the native reds (Lurz et al. 2003). However, other research suggested that approaches that could be considered less humane, such as the use of pine martins as a potential biological control would be a more effective method (Strauss et al. 2012; Sheehy et al. 2018).

The Invasive Alien Species (Enforcement and Permitting) Order came into effect during October 2019. This order puts England in line with the rest of Britain by removing Natural England's power to issue release licenses for Grey Squirrels. Although the effects this order

will have are not yet apparent, it will hopefully help to further aid in the control of Grey Squirrels in the future.

The moral philosophy of environmental ethics presents a challenge for necessary control of invasive species in the preservation of characteristic diversity of a region and the commitment to prevent moral ambiguity (Keller 2011). More specifically the ethical concern of culling of Grey squirrels is addressed within the International consensus principles for ethical wildlife control that "if done in a clear, coordinated and humane way" (Dubois et al. 2017). Grey squirrels are protected under the Animal and Welfare act 2006, with a focus on the use of live capture traps, it is important for animal welfare standards to be met.

This raised issues in the field of veterinary medicine, with what the most suitable action would be to take in the case for caring for and injured grey squirrel, as it is an offence to keep or release them back into the wild as stated in the Wildlife and Countryside Act (Hutchison 2018). However, the question posed is how it would be possible to still act humanely in terms of the animal's welfare. A different opinion on this matter addresses the consequence of the ethical dilemma preventing additional culling of the grey squirrel is seen as problematic for the survival of the red squirrel (Middleton 2009), although it is argued from the RSPCA that killing of the animal is impractical and inhumane in the long run, referring to the grey squirrels ability within their biology to quickly replace the loss of squirrels in an area in as little as a month (RSPCA 2015). Furthermore, the reactionary behaviour of the grey squirrel has shown increased localised density, arguing that culling is not a solution, and may instead assist in the further distribution of this species within a habitat (Lawton and Rochford 2007).

Despite criticism the most common consensus of culling grey squirrels is a necessity for the conservation of red squirrels, the overall impact of grey squirrel activity poses such a threat to habitat and native species to which these methods of control are considered viable (Schuchert et al. 2014). The population of the red squirrels will likely decline in the face of grey squirrel activity. Current policy and conservation techniques require revision to prevent ecological displacement and protect native species.

Summary

Key areas addressed in the grey squirrel case study were the issues relating to the ethics behind eradication programmes. Educating the public on the negative impacts that grey squirrels have (e.g. predating on native birds' nests) can help prevent backlash and gain support for control programmes. However, this case study also highlighted that it is important to formulate strategies and not just arbitrarily cull grey squirrels, as unplanned control can end up being ineffective, wasting time and resources, and killing off squirrels without justification.

4.4 North American signal crayfish

The signal crayfish (*Pacifastacus leniusculus* Dana*)* was first introduced into Europe in the 1960s for angling purposes (Manchester and Bullock 2001). Since its introduction, the signal crayfish has spread rapidly flourishing in European rivers and causing great concern due to its impact on native aquatic ecosystems (Bubb et al. 2004).

As with the grey squirrel, many results for signal crayfish focussed on the biological impacts on England and Wales' native species. The majority of results focussed on signal crayfish impacts in general (38), followed by the dispersal of the species (29). Only 6 results from web of science referenced law and policy in literature, therefore other databases were researched to supplement the legislative research.

In England and Wales, one of the major issues with signal crayfish is its impact on the only native freshwater species of crayfish: the White-Clawed Crayfish (*Austropotamobius pallipes).* Since its introduction in the 1970s, the spread of Signal crayfish in has resulted in a steep decline in populations of White-Clawed Crayfish, which today are regarded as nationally threatened (Bubb et al. 2004). One of the key causes of this decline is the crayfish plague, which is a parasitic infection of the microsporidian parasite *Thelohania contejeani* carried by the invasive species (Hampshire and Isle of Wight Wildlife Trust 2009).

A further impact of the signal crayfish include damaging riverbanks and causing bank collapse due to their burrowing and predating on a variety of fish & amphibian eggs, juveniles and small fish (Inlands Water Association 2018).

Signal crayfish have been reported to significantly reduce invertebrate density to around 60% of that in areas void of any signal crayfish. Furthermore, freshwater invertebrate community diversity and richness is also lower in areas where signal crayfish are abundant (Crawford et al. 2006). It is evident that the signal crayfish disrupts and depletes native ecosystems, impacting on the delicate balance of food webs in habitats they have invaded. Therefore, effective control of signal crayfish in British watercourses is essential for conserving the native ecology.

In the European Union's Water Framework Directive (WDF), there was a requirement for water bodies to reach "good ecological status" by 2015 and one of the reasons for the failure to meet this requirement was due to the presence of invasive crayfish species including Signal crayfish (Cardoso and Free 2008). This did not necessarily have to cause a failure to meet requirements, as the WDF does not explicitly require NNIS to be taken into consideration when assessing the ecological status of watercourses, only implying that they should be taken into account. However, the UK decided to incorporate NNIS into the standard for watercourses, only permitting rivers with no established non-native species to be given a high ecological status (Vandekerkhove and Cardoso, 2010). Although incorporating this requirement into policy creates complications and difficulties in meeting WDF standards, it does demonstrate an effort to address the issue of aquatic NNIS in the UK. While the EU acknowledges the need to control this species is important, the lack of requirement in the framework directive for NNIS control indicates that limited measures have been taken to actually address this issue.

Signal crayfish control methods highlight the issues that can arise due to a lack of research leading to ineffective management control. The most frequently used form of crayfish control has been the use of baited traps. However, recent research indicates that baited traps may not be as effective as previously considered (Green et al. 2018). Whilst they can initially help reduce overall population size, it can cause problems and limitations. Baited traps tend to predominantly attract large male crayfish. The advantage of this is that generally, larger crayfish are harvested for meat so they have a monetary benefit (Harlioğlu and Holdich 2001).

However, trapping only the large male individuals in a population can be an issue, as large male crayfish are aggressive and cannibalistic, predating on smaller individuals in a population (Stebbing et al. 2012). Therefore, by removing them from populations, the biological control through cannibalism is also lessened and the effectiveness of population control becomes less effective and efficient. In order to counter this issue, the use of artificial refuge traps is advised when undertaking signal crayfish management programmes, to achieve more effective trapping across all sizes in the signal crayfish population (Green et al. 2018).

One thing that must always be considered when attempting to control or eradicate an invasive population is the density-dependent process. Density dependency responses occur when there are alterations in the demographic of a population. The main alterations of this seen in signal crayfish are through reproduction and growth. When trapping is undertaken on a crayfish population, it diminishes the size of the population. This decrease in population size has been shown to lead to earlier sexual maturity in female crayfish, which reach maturity faster in order to replenish the population size faster (Freeman and Turnball 2010).

Furthermore, research indicates that for smaller populations of crayfish, individuals tend to grow faster than in larger ones (Parkyn et al. 2002). This is another density dependency response and means that moulting frequency will be higher in smaller crayfish populations and therefore would increase over time when a control measure is put into place.

Due to these density dependency factors, attempts at eradicating populations of the signal crayfish are hampered by the ability of females to mature faster and populations to grow more quickly. This means that successful management would require continuous control or, ideally, total eradication of the crayfish population in an area, otherwise the signal crayfish would likely repopulate the area rapidly, undoing previous control efforts.

It is important to consider public awareness, particularly for them to follow procedures laid out in government campaigns, such as “check, clean and dry”. One study found that only 36% were aware of the ecological risks posed by signal crayfish, furthermore aquatic species in general tend to be less understood by the public (Gozlan et al. 2013) . Therefore it is clear that more needs to be done to educate the public on the negative impacts of NNIS, particularly aquatic species such as the signal crayfish.

Summary

The case study on signal crayfish had several key findings. The first observation was scientific research. Despite baited traps being a popular method for controlling signal crayfish in watercourses, recent research has found flaws in its effectiveness, instead suggesting the use of Artificial Refuge Traps. This highlights the need for an uptake of the best possible practices of control according to the latest scientific research to ensure control efforts achieve the best possible results and are not wasting resources. The effect of density dependency ratios was also addressed, a factor that should always be considered when controlling NNIS populations, so as not to be hinder by rapid repopulation after controlling an area. The study of signal crayfish highlighted the complexities of tackling a widely spread, highly invasive species. However, although total eradication is unlikely for such a extensively dispersed species, with increased public awareness and well organised, targeted efforts using a combination of control techniques, populations of signal crayfish may be managed in

certain environments, with further spread across English and Welsh watercourses being minimised (Gherardi et al. 2011).

4.5 Japanese Knotweed

Japanese knotweed (*Fallopia japonica* Houtt) was introduced to England and Wales from Japan in the Victorian era and has since become widely established along roads, railways and watercourses (Kabat et al. 2006). This high-profile NNIS has a number of detrimental impacts including affecting native biodiversity, increasing flood risks and damaging infrastructure (Fennell et al. 2018).

An estimated 2% of residential sites and 1.25% domestic properties have been impacted by Japanese Knotweed spread in Britain (House of Commons Science and Technology Committee 2019). Economic implications can arise due to causing difficulties in getting a mortgage due to is causing (Fennell et al. 2018). Because of this the value of domestic property can be reduced if Japanese Knotweed is growing on the land (Robinson 2017).

However, the removal of Japanese Knotweed is also complicated, as the Environmental Protection Act 1990 lists the plant as a "controlled waste", meaning appropriate measures must be taken when disposing of Japanese knotweed. This means waste licence is required to remove Japanese knotweed from a site (Cornwall Council 2017). Furthermore, according to government regulations, you need to use the approved herbicides, hold a certificate of competence for herbicide use, carry out a control of substances hazardous to health assessment and get permission from Natural England (and the Environment Agency if close to water) when (Environment Agency 2016). Whilst this is beneficial as it helps ensure that any plant waste is disposed of appropriately, preventing the risk of further spread of Japanese Knotweed through incorrect disposal of plant debris, problems can often arise in enforcing on this act as it is difficult to prove the perpetrator of the offence (Cornwall Council 2017). The complex steps required in proper control may discourage landowners from acting if they discover the species on their land due to the costs and complications associated with its removal.

It may also be noted that the maximum fine from a Magistrates Court of planting or causing Japanese knotweed to grow in the wild is £5000 under the Wildlife and Countryside Act. However, the Magistrates Court can issue a fine of up to £20,000 for disposing of Japanese knotweed incorrectly under the Environmental Protection Act 1990 (Cornwall Council 2017). The financial implications of incorrectly treating and disposing of Japanese Knotweed may also be considered by landowners as a deterrent, since consequences are far greater than if Japanese Knotweed is reported spreading off their land.

However, due to how widespread the species is, the enforcement authority will often enforce on landowners to control the spread of Japanese knotweed by use of the Anti-social Behaviour, Crime, and Policing Act 2014. One benefit of using anti-social behaviour orders to control NNIS, such as Japanese knotweed, is that the local community also hold the rights to trigger an order. This means that they can pick up on and trigger orders for cases of NNIS that official authorities may not yet have recognised. This can help to promote a faster response to sightings of Japanese Knotweed.

However, Japanese Knotweed is not listed in the Weeds Act (1959). Therefore, there is no statutory requirement to report the presence of this species. This is detrimental to the control of Japanese knotweed, as it makes it difficult to analyse the distribution of the species in England and Wales and it is also more difficult to encourage landowners to take control of Japanese knotweed spread, as it is not mandatory unless the species is spreading off their land, at which point the species is often growing extensively and having detrimental impacts on the environment. However, neighbours to your land can report a 'private nuisance' if Japanese Spreads from your land onto theirs, which could encourage proactive responses to control to prevent being reported (Payne and Hoxley 2012).

Although most examples of Japanese knotweed found outside the native range are male-sterile specimens, this plant has been shown to demonstrate clonal growth in England and Wales and reproducing through fragmentation (Hollingsworth and Bailey, 2000). Due to its high abundance along riverbanks, propagule dispersal during high-water events can result in extensive spread of the species (Colleran and Goodall 2014). Focussing efforts to control Japanese knotweed, particularly in areas near watercourses susceptible to erosion is therefore advisable. However, because there is no mandatory requirement for landowners to control Japanese knotweed found along watercourses on their land, Japanese knotweed can still spread in high-water events through this clonal growth. This form of dispersal is not currently addressed effectively by British law, an issue that the Environment Agency in Suffolk experienced on several occasions when attempting to control NNIS plant populations along riverbanks.

Research has indicated that Japanese Knotweed does not cause more damage to infrastructure than many plants that are not subject to such extensive control programmes (House of Commons Science and Technology Committee 2019). However, it has been noted that it does cause other detrimental impacts including outcompeting native species and eroding banks and increasing flood risk where it grows by rivers (Robinson et al. 2017). However, a more measured approach to its control and a risk assessment into Japanese Knotweed and the impacts it has on infrastructure is clearly necessary (House of Commons Science and Technology Committee 2019).

Summary

Japanese Knotweed is a distinctive NNIS due to the economic implications that can arise through property values and its' presence preventing mortgages. Enforcement of Japanese Knotweed can be achieved through anti-social behaviour orders and species control orders, which can be effective in controlling spread when landowners are non-compliant.

However, controlling this species is complicated, as improper disposal of plant waste can result in large fines. Furthermore, many methods of control (e.g. cutting and burying) are ineffective, and there are numerous steps required to ensure control of Japanese Knotweed is undertaken in the legally approved approach, often resulting in control being a lengthy and expensive task.

4.6 Successful Management of NNIS in England and Wales

The case study examples demonstrate that for many NNIS that have been allowed to establish and disperse, effective control and/or eradication is not possible. This highlights the need to focus on preventative measures to stop more NNIS from establishing in England and Wales through actions such as horizon scanning and effective biosecurity.

However, there have been examples of successful NNIS control programmes in England and Wales. One example of this was the Muskrat that were introduced in the 1920s to farm for fur. With detailed planning and organisation, an eradication scheme was put into motion in 1932 and within 10 years, the campaign was successful in removing Muskrats from the wild in Britain (Gosling and Baker 1989). More recently, the Ruddy Duck, which was an accidental release in the 60s from waterfowl collections, has seen a population reduction of over 95% in the wild across Britain due to successful culling programmes (Henderson at al. 2010).

Although there are still several high profile NNIS, such as the case studies investigated in this study that are abundant across England and Wales, British law has developed greatly in recent years, with efforts being made towards risk analysis, horizon scanning, pathway analysis and contingency planning to create a more proactive response for controlling NNIS spread (Moore 2021). Whilst it is important to be ambitious with NNIS control programmes going forward achieving eradication where possible, caution should also be taken to ensure that resources are not wasted on inefficient and ineffective control programmes (Baker 2010).

Chapter 2: Investigating Stakeholders Views on the Effectiveness of Law and Policy in Preventing and Controlling NNIS Spread in England and Wales

5 Introduction

This study has explored whether there is any incoherence between law and policy and scientific research surrounding NNIS. However, it also aims to establish whether current law and policy is addressing the reality of the issues faced by stakeholders in practical scenarios. This chapter will use questionnaires to capture stakeholders' experiences with NNIS and investigate their opinions of current law and policy, which is essential in determining the applicability of current control methods of NNIS within England and Wales (DEFRA 2003; Reed and Kurzon 2015; Kapitza et al. 2019). Furthermore, stakeholders have a unique understanding of NNIS that may not be picked up by academic literature, therefore their input will assist in a more comprehensive study (Bayliss et al. 2013).

Undertaking a systematic critical analysis of the literature on NNIS law and policy in England and Wales enabled the identification of key topic areas that were frequently addressed in research to be included in the questionnaire. The key topics of biosecurity, law and policy, enforcement, scientific research, and education and public awareness were included in the questions addressed to stakeholders.

6 Methods

To create a questionnaire with a clear format, security for data protection, and to be able to easily distribute the questionnaire to a wider audience (particularly in current COVID-19 conditions, where distributing questionnaires in person would have been problematic), JISC's online survey was used (https://www.onlinesurveys.ac.uk/).

When distributing the questionnaires, emails were sent to contacts from the Environment Agency, Natural England, National Farmers Union, and several environmental NGOs and universities. Snowball sampling (i.e. requesting in the emails for respondents to forward on the questionnaire and/or refer us to other potential respondents) was used as a tool to widen the audience and receive more responses. The questionnaire was also forwarded to a representative from the Wildlife and Countryside Link and posted on the Wildlife Trusts intranet. As responses were returned, the representation of different occupations was monitored, and efforts were made to contact more potential respondents from professions that had less representation, to ensure a more even spread of responses. Research suggested a minimum of 30 participants would be required for effective data analysis for the questionnaire, therefore the goal was to receive a minimum of 30 responses (Paltridge and Aek Phakiti 2010).

Although the aim was to receive as many responses as possible, it was still important to target stakeholders with a knowledge of NNIS, therefore sampling was kept to those with a professional environmental background. Questions were also asked to establish whether stakeholders had a good level of knowledge and understanding of the impacts of NNIS and the current law and policy surrounding NNIS in England and Wales. The questionnaire also included hierarchal questions to identify which areas stakeholders considered to be the most important for NNIS control. This method created an effective ranking system, which could be used to identify and prioritise the most important methods of NNIS control according to stakeholders (Rey-Valette et al. 2017).

Following on from this, the questionnaire asked the respondents' views on major areas of law and policy relating to NNIS and the key concerns and recommendations identified through the systematic review.

It was important to create an effective questionnaire that provided desirable results, whilst remaining easy and not too time consuming for the stakeholders to complete, to ensure optimum response rates (Krosnick 2017). To achieve this, categorised questions were used where possible with a Likert scale that had answers ranging from strongly agree to strongly disagree. To ensure each question was clear and concise, the following steps were taken:

1. Use simple, short words and sentences
2. Ensure only one question is asked at a time
3. Ensure that questions do not have a double-meaning
4. Ensure questions are not biased or leading
5. Create a sensible structure for the questionnaire (clearly sectioned with each topic progressing from "general" to "specific")

It was considered for each question, the option to "don't know" was also include so that stakeholders did not feel the need to answer questions they were unsure or less knowledgeable on. However, this option was not chosen, as it was counterproductive to ensuring maximum attitudinal responses for the questionnaire. However, for questions on the Likert Scale, the option to "neither agree nor disagree" was included. Although some studies argue that this gives respondents an easy option that requires minimal cognitive effort and may not reflect their true opinions, this has been shown to be more of a concern for respondents with low cognitive skills and less interest in the questionnaire topic (Krosnick et al. 2001). The questionnaire for this study is focussed on stakeholders with an invested interested and reasonable level of knowledge of the topic in question- non-native invasive species- therefore the likelihood of their answers not being reflective of their views if given the "neither agree nor disagree" option was considered unlikely.

Furthermore, it was decided to add a few questions at the beginning of the questionnaire to determine stakeholder's familiarity with the laws and policies for controlling NNIS in England and Wales. The level of knowledge amongst stakeholders was gauged and stakeholders that responded as being "unfamiliar" with the topic were discredited from the subsequent questions. This approach was limited however, as although it gives a general idea of the respondent's familiarity with the topic, the responses will be a perception of people's knowledge, so may not be the most accurate way of assessing their knowledge. However, these questions were still considered important for interview selection, as it was deemed appropriate to choose a candidate who felt at least "fairly familiar" with the topic, to ensure they would be able to provide confident and informative responses during interviews. In order to gauge people's knowledge and experience of

NNIS further, the question: "In what ways have you come across NNIS in your line of work?" was included.

"Further comments" sections were included after each question to give stakeholders a chance to expand on their answers. The use of this method ensured that questions were easy and quick to answer, whilst still allowing responders to elaborate if they so desired.

Prior to sending out the final product, the questionnaire was piloted using a cognitive interviewing approach in to ensure the utility, readability, and face validity of the questionnaire. To ensure effective piloting, two pilot testers were chosen, one of whom had an academic background in the field of social science, who helped to ensure questions were clear, non-bias and that the questionnaire had an appropriate design, which would achieve the desired responses. The other pilot tester had a background in NNIS management, to ensure questions were relevant to the subject area and clearly and appropriately worded. Adjustments were then made accordingly to improve the questionnaire before sending out to stakeholders.

At the end of the questionnaire, the stakeholders were asked if they would consent to an interview to allow for more comprehensive questioning. This aimed to give stakeholders the opportunity to voice their opinions in a more unrestricted way.

Having assessed the different types of interview, a semi-structured format was deemed the most suitable for this study, due the competency of the participants involved and previous studies demonstrating that this method was effective (Bernard 2017; Hoyle et al. 2017). Unlike fully structured interviews, the semi-structured approach allowed the interview to remain on topic, whilst allowing the participants to and share their experiences and knowledge more freely. The methods for conducting a semi-structured interview from Bernard (2017) were used. This involved creating a list of open-ended questions that would be addressed to the interviewee in a particular order to cover the necessary criteria. Techniques such as the "echo probe" of repeating the respondent's comments and the "uh-huh" probe of making affirmative comments to encourage longer narratives from respondents were uses. These were effective tools in the interview for helping promote lengthy responses, whilst remaining a neutral party. Although lengthy questions were asked to clarify what was being asked, leading questions were avoided, by only using assertions from information already gathered from the interviewee through previous answers or from their questionnaire. For example, one interview commented regarding the ethical concerns of NNIS control during the questionnaire, therefore they were asked:
"So you had an answer here about us using more humane methods such as sterilization for that. Did you want to expand on that a little bit and how you could go about creating more ethical solutions to invasive species control?" This encouraged the topic of conversation to flow, whilst still remaining a neutral party.

Part of the interview focus was on the responses given in the questionnaires, asking stakeholders to give reasoning for their answers as well as investigating areas of particular interest (for example, results that showed similar responses from most applicants or questions with unexpected responses from the questionnaire). Stakeholders were asked which species' they consider to be of particular concern, so that responses could be compared to the results from the selection review, to establish whether the focus of scientific studies is consistent with the most problematic species from a stakeholder's perspective.

Several questions in the interview also focused on the case study species from the literature review. These questions aimed to determine the stakeholder's views of the law and policy, when

applied to particular species, to give a more thorough and in-depth understanding and establish where there may be gaps in knowledge and issues with controlling NNIS spread.

The interviews took place online via a Zoom Web call and the respondents were interviewed for 30-60 minutes, to ensure each interviewee was given a reasonable amount of time to express their answers and viewpoints.

6.1 Analysis Techniques

Initial observational analysis of the questionnaires was undertaken to establish patterns and trends, comparing different responses, and noting key areas of interest to include in the semi-structured interviews. One of the key objectives was to establish whether stakeholder's views differ from the conclusions drawn from the systematic and case study reviews. The questionnaire and interviews responses also highlighted any key issues faced by stakeholders regarding NNIS and suggestions for improving law and policy to control NNIS more effectively in the future.

To effectively analyse the results of the questionnaires and interviews, a number of techniques used by other researchers were investigated (Bazely 2009; Newing 2011; Bernard 2017; Twitcher 2019). Qualitative data analysis was the core technique used in this research to compare and discuss results from the questionnaires and interviews, however, to further investigate some of the relationships and trends of the data, some descriptive statistics of the questionnaires was also incorporated. For the questions regarding the importance of different factors in effective control and how effectively the government used these factors, the mean and confidence intervals were measured, as the values were numerical on an interval scale (1-10) rather than an ordinal measurement scale (Boone and Boone 2012).

6.2 Interview Analysis Techniques

For the interviews, a coding method was initially used to highlight key themes and similarities identified in interviews. Coding is essentially marking notes of text with standardized "codes" that indicate when certain topics or themes have been addressed in an interview (Newing, 2011). Upon receiving questionnaire responses, predefined codes were generated based around themes that were considered likely to be of particular focus; several key coding themes (known as Nodes in the NVivo software) were created prior to interviews, as they were anticipated to come up (Table 9). This use of coding helped to highlight key themes and relationships when analysing the semi-structured interviews.

For the qualitative analysis of the results, a thorough analysis was essential, with the ability to cross-compare responses and establish key themes. To achieve this, it was decided to use the NVivo tool. NVivo helps to manage the coding of qualitative data efficiently and with minimal time consumption. Using this tool helps to create a transparent, repeatable method, creating structured results and helping to code the qualitative data effectively.

The first step of the analysis process was to transfer the questionnaire and interview data into a useable format. For the questionnaires, the "further comments" from respondents were uploaded for the qualitative data analysis. For the interviews, Zoom recordings had transcribed the interviews. However, due to many inaccuracies in the transcripts, each Zoom interview was listened to and "re-transcribed", with all changes made to the transcripts to ensure they were correct. The transcripts were then uploaded to NVivo for analysis.

In order to ensure a good structural plan was followed, the qualitative analysis followed the three-step process set out by Pat Bazley (2009). The three steps of this formula are as follows:

> Describe: outline the major categories in the study, for example in this study, the occupations of different respondents. Look at the major themes and the key points made about them by respondents and how many respondents mentioned them.
>
> Compare: analyse different themes and how they relate to other themes, begin to look at relationships between different answers. Begin asking questions about the data and record meaningful associations.
>
> Relate: make more detailed comparisons and connections, go deeper into the analysis and ask more questions. Try to understand why themes appeared and why they were related to other themes in the ways they were. Interpret what the data results mean and what conclusions can be made in the discussion following from the data analysis.

For phase 1: Describing the coding, the aim was to code the general themes together from all the questionnaires and interviews. The first step was to outline the major categories in the study. This was achieved through manually coding each interview. Any comments from the questionnaire were then coded to the appropriate nodes afterwards or to new nodes that were created for themes discovered during the coding process.

For phase 2: Comparing results, a concept map was designed, linking the different nodes and displaying the different connections between themes to then be discussed. A concept map is a useful tool for analysing interviews and illustrating meaningful relationships (Anzovino and Bretz, 2016). Given the broad range of questions covered in the primary research for this study, it was therefore considered an appropriate method for this study.

From clearly displaying the results in this way, it gave clarity to links and interesting discussion points from the interviews. The key categories identified from the interviews were discussed and analysed in more depth in phase 3.

7 Results

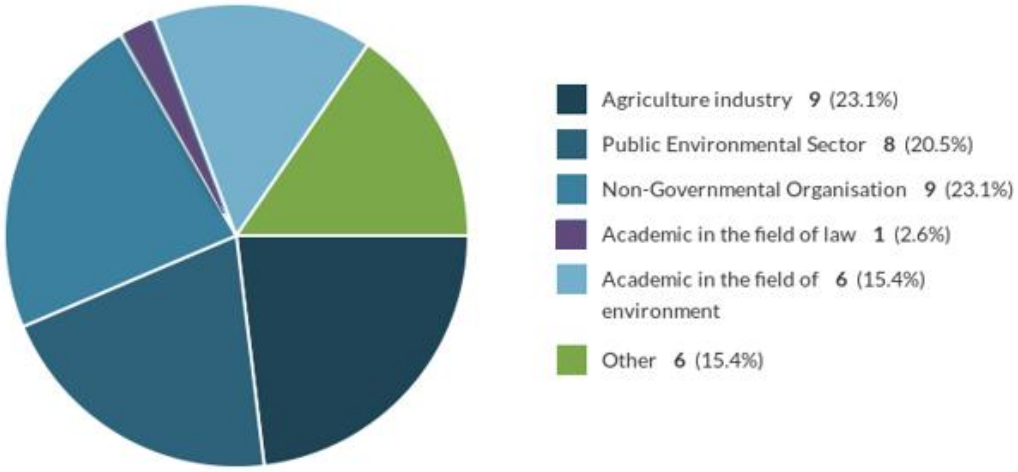


Figure 5: Proportion of the professions of respondents

There was a fairly even proportion of respondents from different work professions represented in questionnaire responses, with reasonable representation from academics in the field of environment, governmental, agricultural and NGO workplaces. There were also several representatives from other fields of work. Those that listed their work as other were someone from a representative body, a landscape gardener, freelance ecologist, food-chain academic and a retiree. There was only one representative from the field of academic law, however, two other respondents listed law and policy work when answering in what ways they had come across NNIS in their field of work and a further four respondents from other professions listed academic research for this question. The relatively even representation of different professions demonstrates that the aim to distribute the questionnaire evenly to represent all areas was successful.

Table 7 below, details the levels of knowledge and understanding of respondents in the topic area. Although this question was subject to the respondents' opinions and therefore not as reliable, the responses were assessed alongside the information received regarding their field of work and also question 5, which asked in what ways the respondents had come across NNIS in their field of work. By assessing this combination of information, I was able to ensure that respondents had enough knowledge in the topic area to give informed responses. I was also able to select the most suitable candidates for interviewing and giving more detailed information.

Table 7: Results for how familiar respondents feel they are with the topic areas

	Number of respondents	
Option	**The impacts of NNIS**	**Law and policy of NNIS**
Very Familiar	20	10
Fairly familiar	16	18
A little familiar	1	5
Not very familiar	2	6
Unfamiliar	0	0

The following graphs (Figures 6 and 7) display the results for question 6 of the questionnaire, which addressed key topic areas and aimed to establish not only how important respondents considered these areas in achieving successful NNIS control, but also asked how effectively they considered that the Government was addressing and using these different factors in order to achieve NNIS control and prevent further spread in England and Wales. Comparing these results aimed to establish what areas are considered the most important in achieving control and assess whether any areas of importance have been overlooked by current government measures.

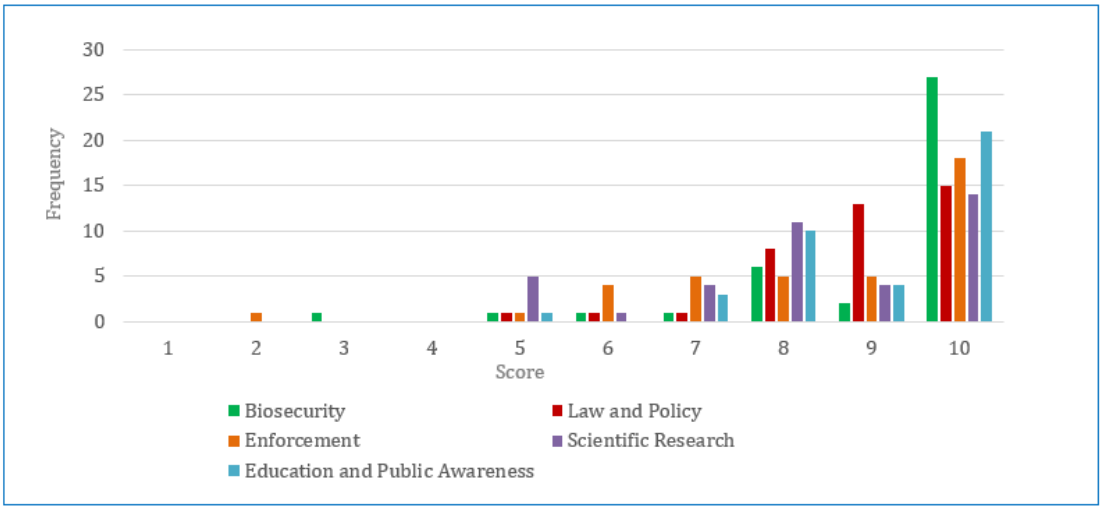


Figure 6: Frequency of respondents' scores for the importance of different factors in establishing effective NNIS control with 1 being least important and 10 being the most important

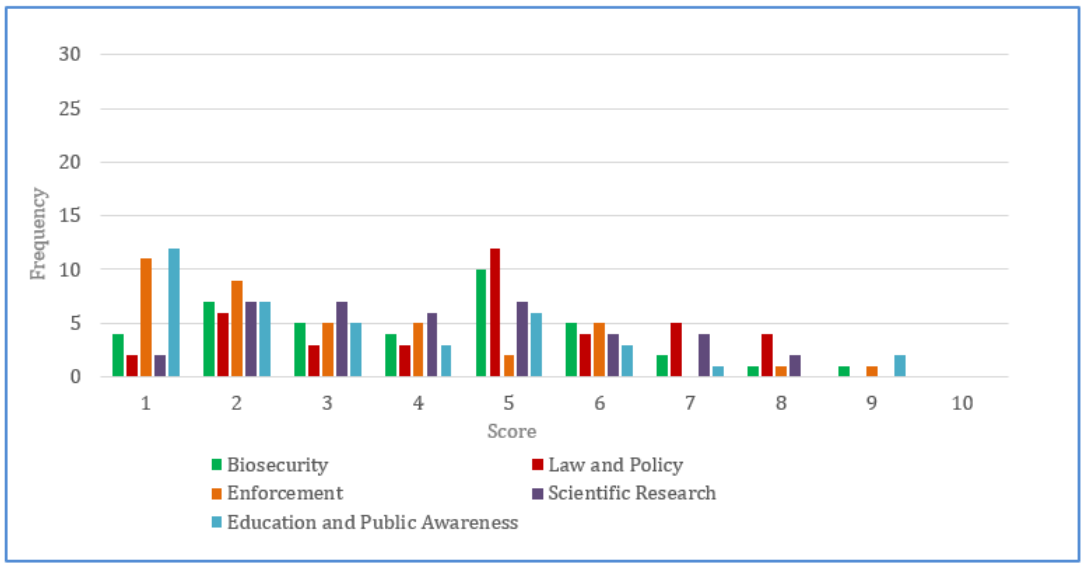


Figure 7: Frequency of respondents' scores for how effectively the Government have implemented different factors to achieve NNIS control with 1 being least important and 10 being the most important

Figure 6 clearly shows that for all five factors, respondents scored them as important when considering non-native invasive species control, with a score of 10 returning the highest frequency for all factors. Figure 7 shows a wider variety of scores for each factor, suggesting more mixed opinions on how effectively the government has implemented each factor, although there is clearly a higher frequency of scores of 5 or below. The highest frequency of respondents for biosecurity and law and policy scored government effectiveness as a 5 whilst the education and enforcement both had the highest frequency of respondents giving the lowest score of 1. Scientific research more varied, with the same number of respondents giving scores of 5, 3 and 2. No respondents scored any of the factors 10/10 for government effectiveness, indicating that all respondents believe government management could be improved to achieve better NNIS control and prevention.

Figures 8 and 9 below shows the mean scores for each category, with confidence intervals (Alpha = 0.05). The confidence intervals overlapped showing there were no significant differences between categories, however, none of the confidence intervals for importance scores and government use overlapped, indicating that for all five categories, stakeholders scored significantly higher for importance than for how effectively the government have implemented the categories.

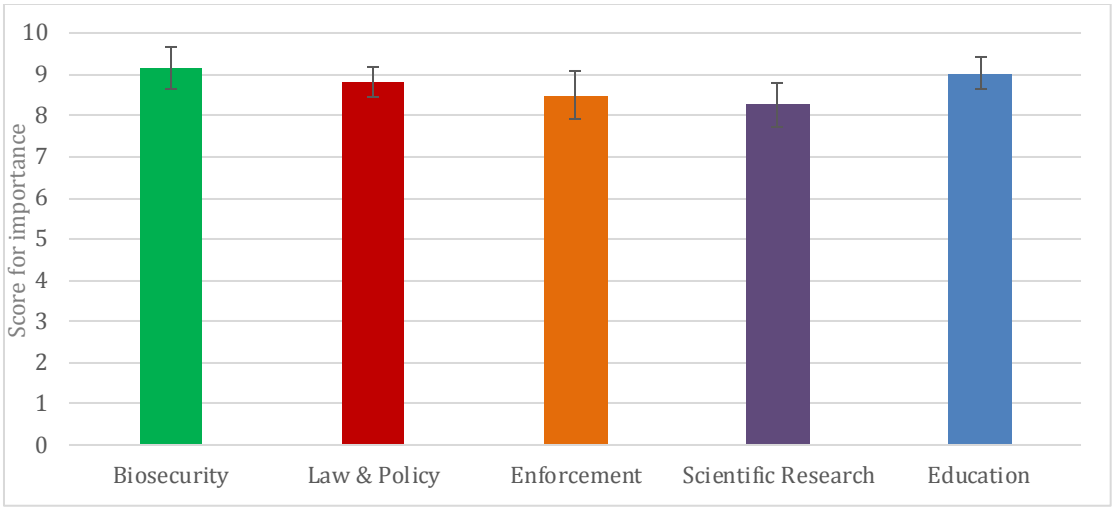


Figure 8: Mean scores of respondents, with confidence intervals (Alpha = 0.05) for the importance of different factors in establishing effective NNIS control with 1 being least important and 10 being the most important

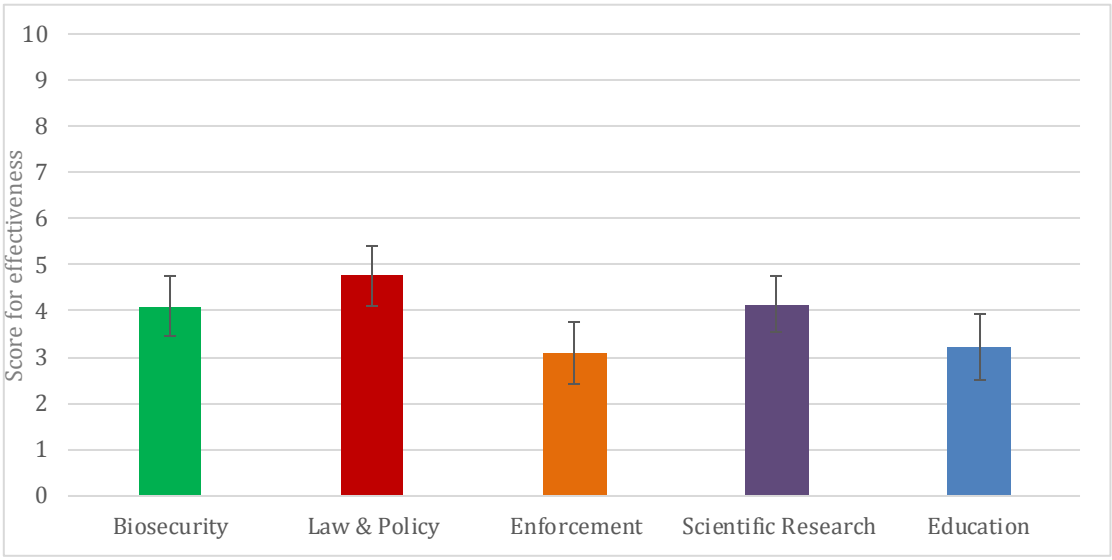


Figure 9: Mean scores of respondents, with confidence intervals (Alpha = 0.05) for how effectively the Government have implemented different factors to achieve NNIS control with 1 being least important and 10 being the most important

7.1 Different professions

It was considered that respondents from different professions may have different priorities when considering the importance of each factors and how effective they consider the government's effectiveness in these areas to be. Where possible, respondents that selected "other" were categorised with the most suitable category (e.g. all respondents of academic professions were categorised together), however, some respondents with unique professions had to be excluded from this section, but were still included in the "all professions" analysis. The mean scores for each profession are displayed in figures (10 and 11).

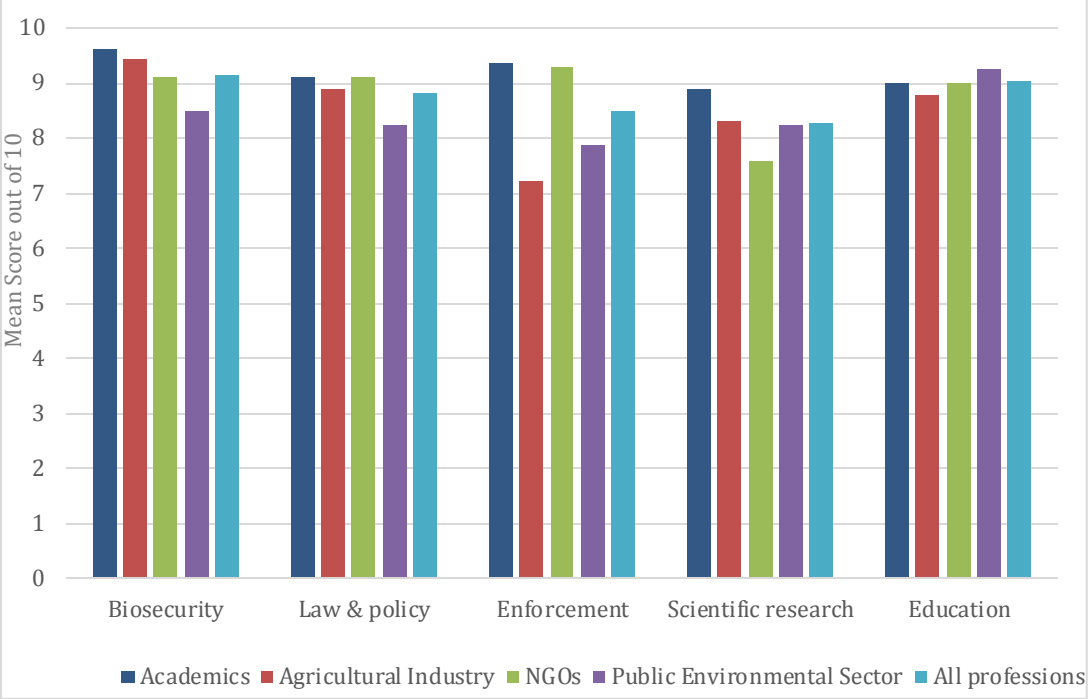


Figure 10: Mean scores for different professions of the importance of each category in achieving effective NNIS control, where 1 is least importance and 10 is most important

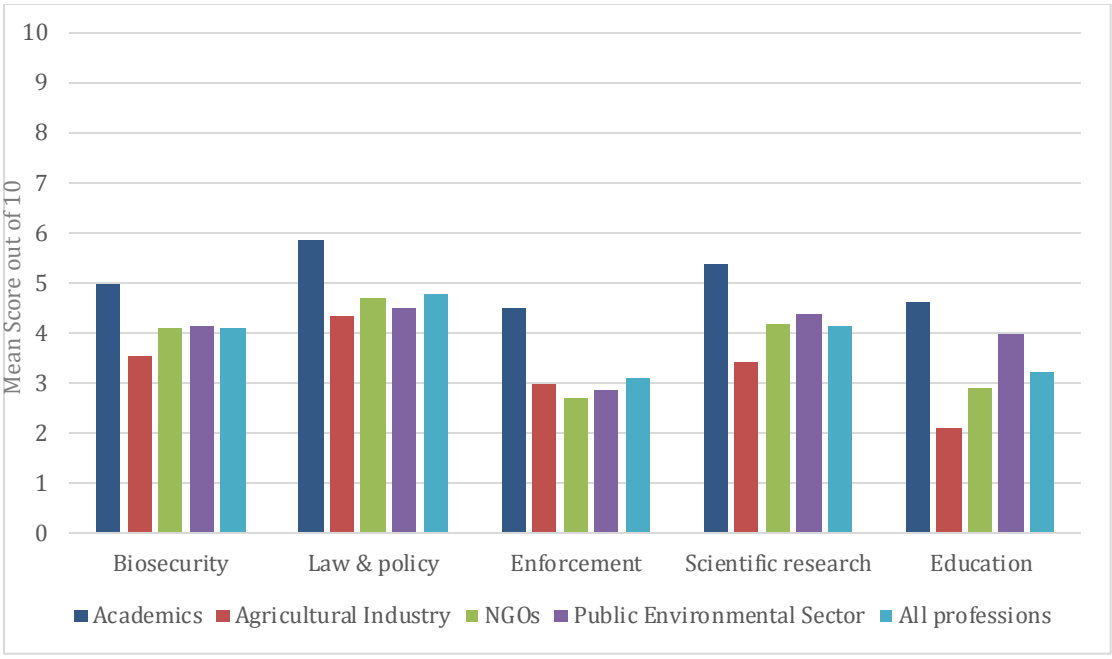


Figure 11: Mean scores of different professions for how effectively the government has applied each category in achieving effective NNIS control, where 1 is least effectively and 10 is most effectively

7.2 Importance of each factor in achieving effective NNIS management

Respondents scored highly in all factors, with mean scores from all respondents ranging from 8.28 (*SE* = 0.27) in scientific research to 9.15 (*SE* = 0.26) for biosecurity. This shows that all of these areas were considered extremely important in achieving effective NNIS control. Standard deviation for these results was always lower than 2, showing that there was some variation in results, but the majority of respondents still scored relatively highly for each of the factors.

Results showed that there were not any major differences in opinions across the professions, with similar mean scores for each factor. However, there were some differences in scores across different professions. For biosecurity, the public environmental sector scored importance 8.5 (*SE* = 0.89) on average compared to other professions all scoring over 9 and a mean across all professions of 9.15 (*SE* = 0.26). Again for law and policy the public environmental sector had the lowest average score of 8.25 (*SE* = 0.53). As academics had given the highest average scores for both these factors and public environmental sector the lowest, it was considered that respondents from different professions were scoring more or less generously, however, for education, the public environmental sector gave the highest average score of 9.25 (*SE* = 0.37), which negated these concerns.

There was less difference in average scores for education, with respondents across all professions scoring highly. For enforcement, academics and NGOs scored similarly with means of 9.38 (*SE* =0.38) and 9.3 (*SE* = 0.37) respectively, as did the agricultural and public environmental sectors, scoring 7.22 (*SE* = 0.83) and 7.88 (*SE* = 0.64). Enforcement also had the highest standard deviation scores, demonstrating that there was mixed opinions amongst respondents as to how important this factor was. As would be expected,

respondents from academic fields scored scientific research the highest on average for importance with 8.88 (*SE* =0.48), but only by a small margin, with all professions having similar average responses except for NGOs, who scored slightly lower on average, with a mean of 7.6 (*SE* =0.54).

7.3 Government Effectiveness in achieving effective NNIS management

For all five categories in each profession, as well as for all respondents, the average scores for how effectively the government were implementing the factors were much lower than scores for importance (biosecurity scoring 5.05 lower, law and policy 4.05 lower, enforcement 5.39 lower, scientific research 4.15 lower and education 5.8 lower). This highlighted the stark difference in responses for the two questions, which can be seen in figures (10 and 11).

The mean score for each factor was lower than 5, with the highest scoring 4.77 (*SE* = 0.33) (law and policy) and the lowest scoring 3.1 (*SE* = 0.34) (enforcement). This indicates that in general, stakeholders view the government to have applied biosecurity, law and policy, enforcement, scientific research, and education ineffectively in preventing and controlling NNIS spread, indicating the need for changes in all of these areas.

The standard deviation was calculated as much higher for government use than the results for how important respondents considered factors, ranging from a deviation of 1.99 for scientific research, to 2.27 for education. This indicates that respondents scores were widely distributed, and there were very mixed opinions on how effectively the government implemented different factors. Standard error scores for government use were also higher, indicating that the mean scores for importance were closer to the true mean of stakeholders, with more uncertainty as to how close the results represent stakeholders views.

When respondents' scores for importance of each factor were cross-compared with their scores for government effectiveness, the results found that nearly all respondents gave higher scores for importance of each factor than the corresponding score for government effectiveness, with only 6 responses scoring both answers equal scores and 4 scoring government effectiveness higher than importance. This only accounted for 5.1% of responses. Indicating that most respondents felt more could be done in each of the areas to achieve better NNIS management.

When observing the differences in scores for different professions, there was very little variation amongst respondents. However, it was observed that for all five factors, academics gave the highest average scores. This suggests that academics consider current NNIS control and prevention measures implemented by the government to be more effective than other professions, however, it is also possible that respondents from academic professions were more generous in their scores than other professions. The lowest average scores for government effectiveness were given by NGOs (biosecurity and enforcement) and the agricultural industry (law and policy, scientific research and education). However, as all average scores were similar and there was a standard deviation of 1.99 or higher for this question, the only deduction that can be reasonably made is that stakeholders from all professions in the survey considered current government effectiveness had a lot of room for improvement.

Although the mean scores from professions were not remarkably different from one another, the results still demonstrated that in some cases there were differences in average scores, highlighting the need for the government to incorporate the viewpoints of stakeholders from a variety of different professions to gain a clear insight into their experiences and opinions.

Question 7 of the questionnaire investigated whether, from a stakeholder's perspective, social, economic, and environmental factors are considered equally when law and policy is made and in the prioritisation of NNIS for control programmes.

When creating the question, it was hypothesised that results would indicate:

- The creation of law and policy and prioritisation of NNIS for control will both have similar considerations for social, economic and environmental factors
- Social, economic and environmental factors will not be equally considered for law and policy or NNIS prioritisation

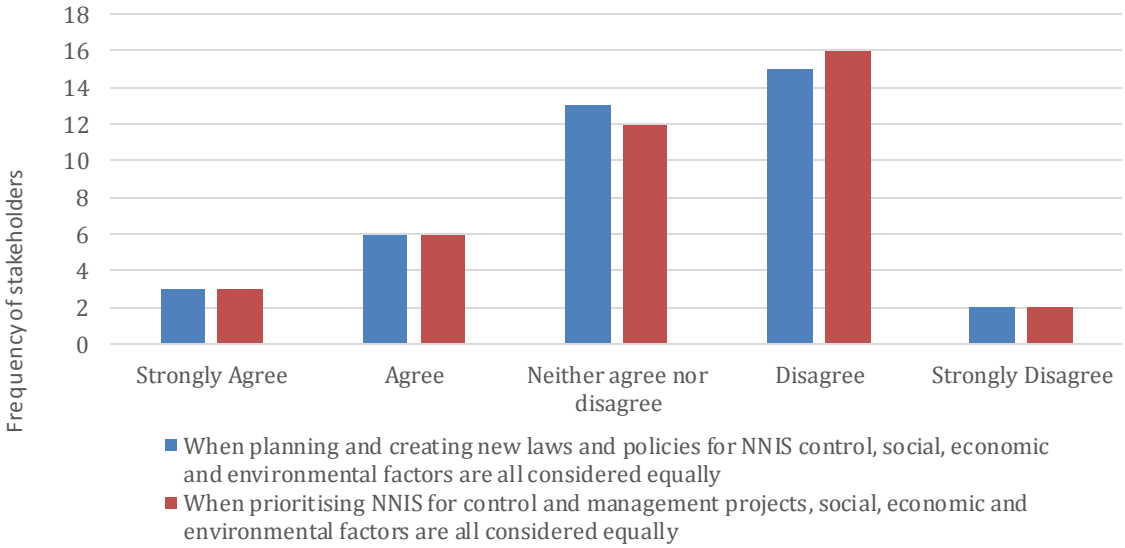


Figure 12: Frequency graph for the extent to which stakeholders agreed that social, economic and environmental factors are considered equally when creating legislation and when prioritising NNIS for control.

Results from question 7 indicate that similar patterns were shown for both statements, with the mode of both being "disagree". The data shows that although more stakeholders disagreed or strongly disagreed with social, economic and environmental factors being considered equally for both creating new laws and policies for NNIS control (frequency = 17) and when deciding which species are prioritised for control programmes (frequency = 18) than those that agreed (frequency = 9 for both statements), a large proportion of respondents also selected "neither agree nor disagree" for both questions (frequency = 13 for law and policy and frequency = 12 for prioritising NNIS for control). This demonstrates a high level of uncertainty amongst respondents for this question and that further investigation would be necessary to determine stakeholders viewpoints on this question.

7.4 Stakeholders Views on Key NNIS Ideas and Statements

Question 8 of the questionnaire investigated several topics from the systematic review and ideas raised in the NNIS Environmental Audit Committee (2019). Figure 13 indicates whether respondents agreed or disagreed with each of these statements. The key aim of this question was to assess to what extent stakeholders agreed with each statement and whether some statements showed higher or lower levels of agreement.

Figure 13 shows that most of the respondents either agreed or strongly agreed with all the statements, with the modal result for statements 1, 2, 3 and 4 being "strongly agree" and the modes for statements 4 and 5 being "agree". The statement that the highest percentage of respondents agreed or strongly agreed with was statement 4, with 89.7% of respondents agreeing that this was a good idea. Statement 6 was disagreed or strongly disagreed with the most, with 18.9% of participants responding that this would not be a good idea. All statements had respondents that were unsure or had no opinion so selected "neither agree nor disagree", this response ranges from 7.7% of respondents for statement 4 to 29.7% for statement 3. It was predicted that there would be a mixed response for question 3, as the ethics behind culling is a controversial topic in the field of NNIS. Although the statements demonstrated a high level agreement from responses, it was considered important to investigate views further, therefore these questions were investigated in more depth in the interviews, to explore the positive and negative views of each statement.

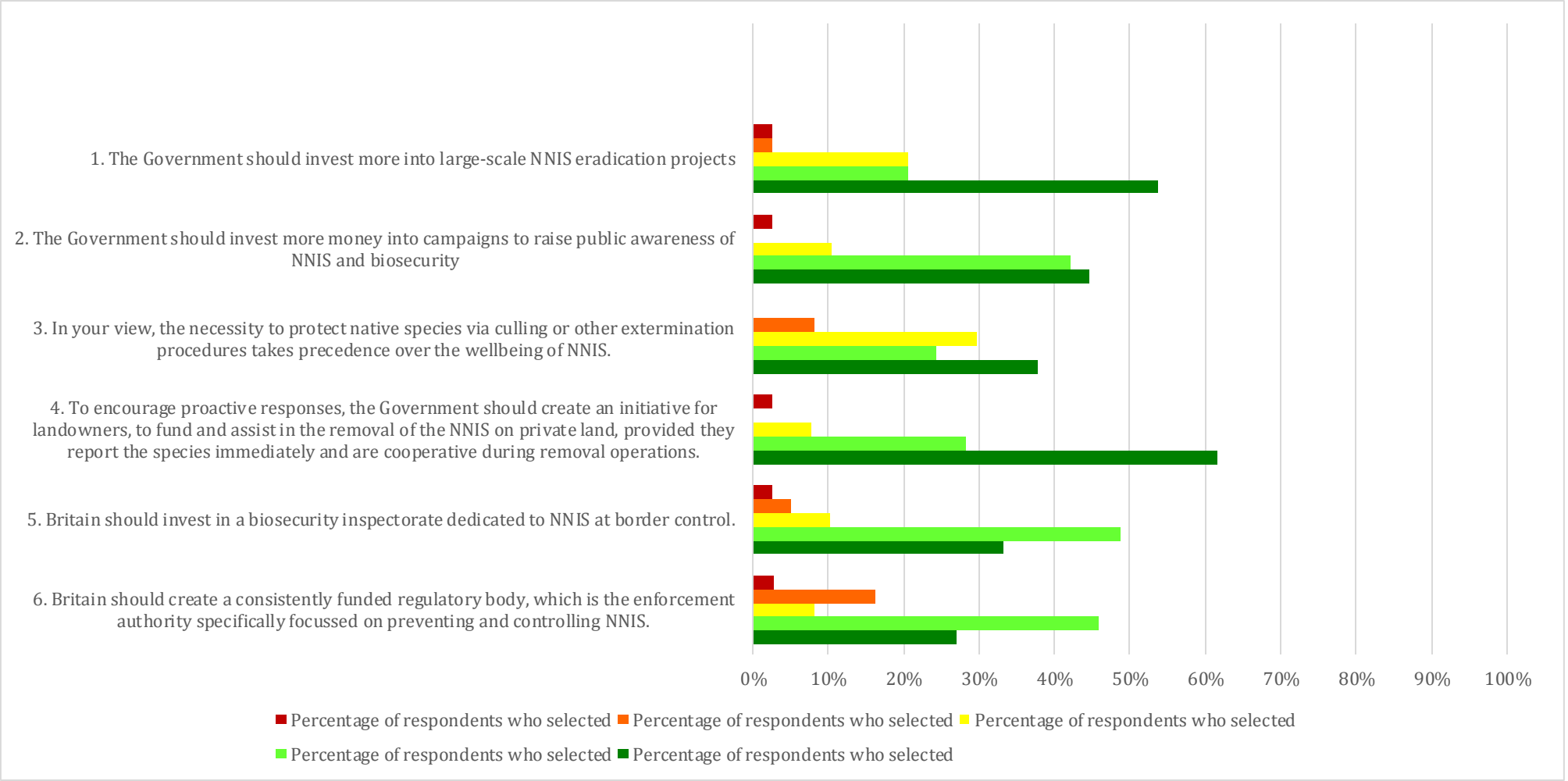


Figure 13: Stakeholders opinions concerning statements relating to NNIS legislation and management

8 Interview Results

8.1 Professions of Participants

Table 8: Professions of Interview Participants

Participant 1	Academic in field of Environment
Participant 2	Non-Governmental Organisation
Participant 3	Public Environmental Sector
Participant 4	Other (Representative Body)
Participant 5	Agricultural Industry
Participant 6	Public Environmental Sector
Participant 7	Non-Governmental Organisation
Participant 8	Agricultural Industry

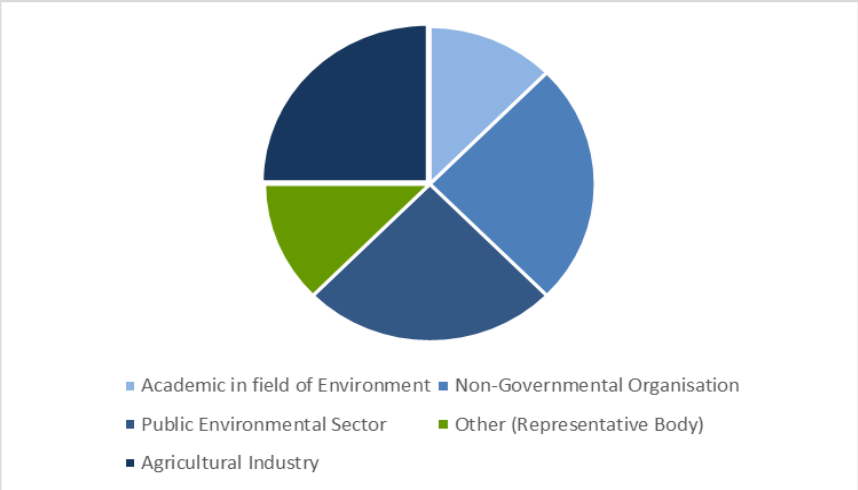


Figure 14: Proportion of Interview Participants from Different Professions

Interviewees were selected from respondents who consented from the questionnaire. Twenty respondents consented to being interviewed, from these, respondents who selected "familiar" or "very familiar" regarding their knowledge of both NNIS and the law and policy of it were contacted for interview. Several respondents did not respond or were unavailable during the interview times. However, eight respondents of different professions were available for interview. Although this was a small sample size, the similarity between Figure 14 and Figure 5 demonstrates that the representation of professions was still proportional to that of the questionnaires.

8.3 Codebook:

The phase 1 nodes that were created are listed in Table 9, listing how many responses were coded to each node listed. Public involvement was the most highly discussed topic in interviews, followed by the limitations of NNIS and reasons against control.

Table 9: The Number of Codes Associated with Key Category Nodes

Node Reference	**Number of codes**
Prevention and Biosecurity	38
Control efforts	34
Law and Policy	29
Responsibility and Enforcement	15
Blacklisting vs Whitelisting	25
Getting people involved	107
Scientific Research	14
Reasons against managing NNIS	42
Potential Limiting Factors (time, resources, and money)	64
Grey Squirrel	21
Japanese Knotweed	23
Signal Crayfish	17
Other names NNIS	29

Figures 15-18 display the major categories (parent nodes) broken down further into subcategories (child nodes). This helped to categorise themes further, giving a more depth analysis of stakeholders' viewpoints. The flow diagrams display the breakdown of the parent nodes and the number of codes (n) in each node listed (i.e. the number of times each category and subcategory was references by participants). Where categories were clearly split into positive and negative statements, they were categorised as such, for other categories, child nodes were created for the key areas that were addressed within a category.

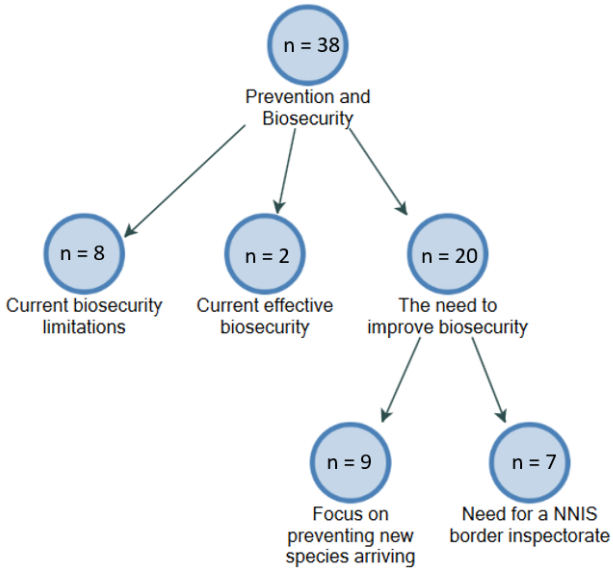


Figure 15: Flow diagram of nodes relating to Prevention and Biosecurity of NNIS, where "n" refers to the number of codes in the node

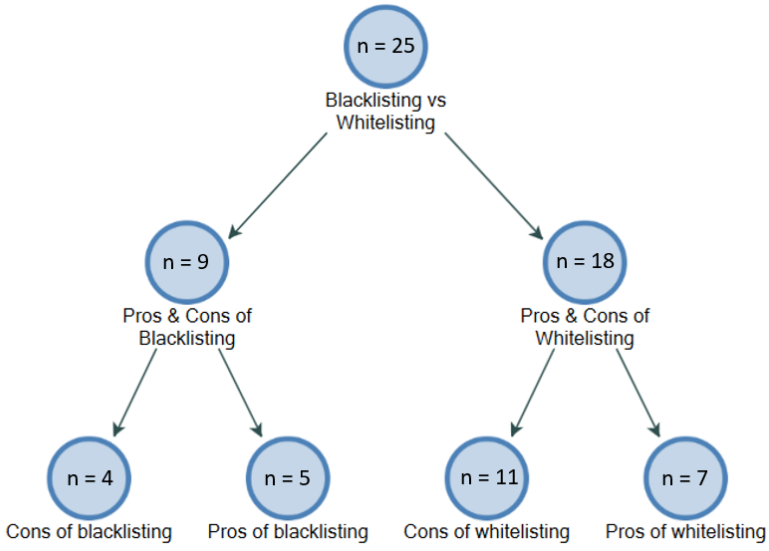
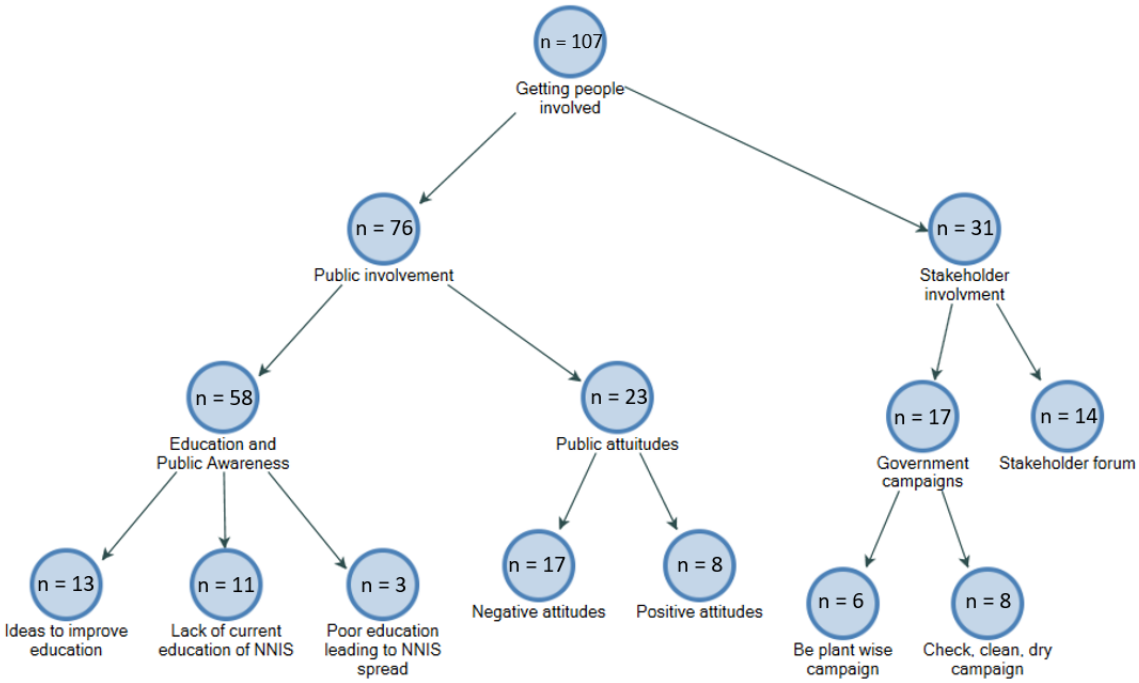


Figure 16: Flow diagram of nodes comparing Blacklisting vs Whitelisting, where "n" refers to the number of codes in the node



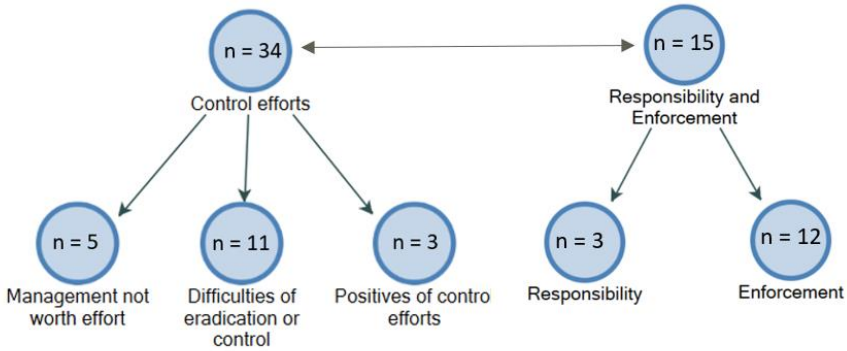


Figure 18: Flow diagram of nodes relating to NNIS and Responsibilities and Enforcement, where "n" refers to the number of codes in the node

Figure 17: Flow diagram of nodes relating to Public and Stakeholder involvement in NNIS prevention and control, where "n" refers to the number of codes in the node

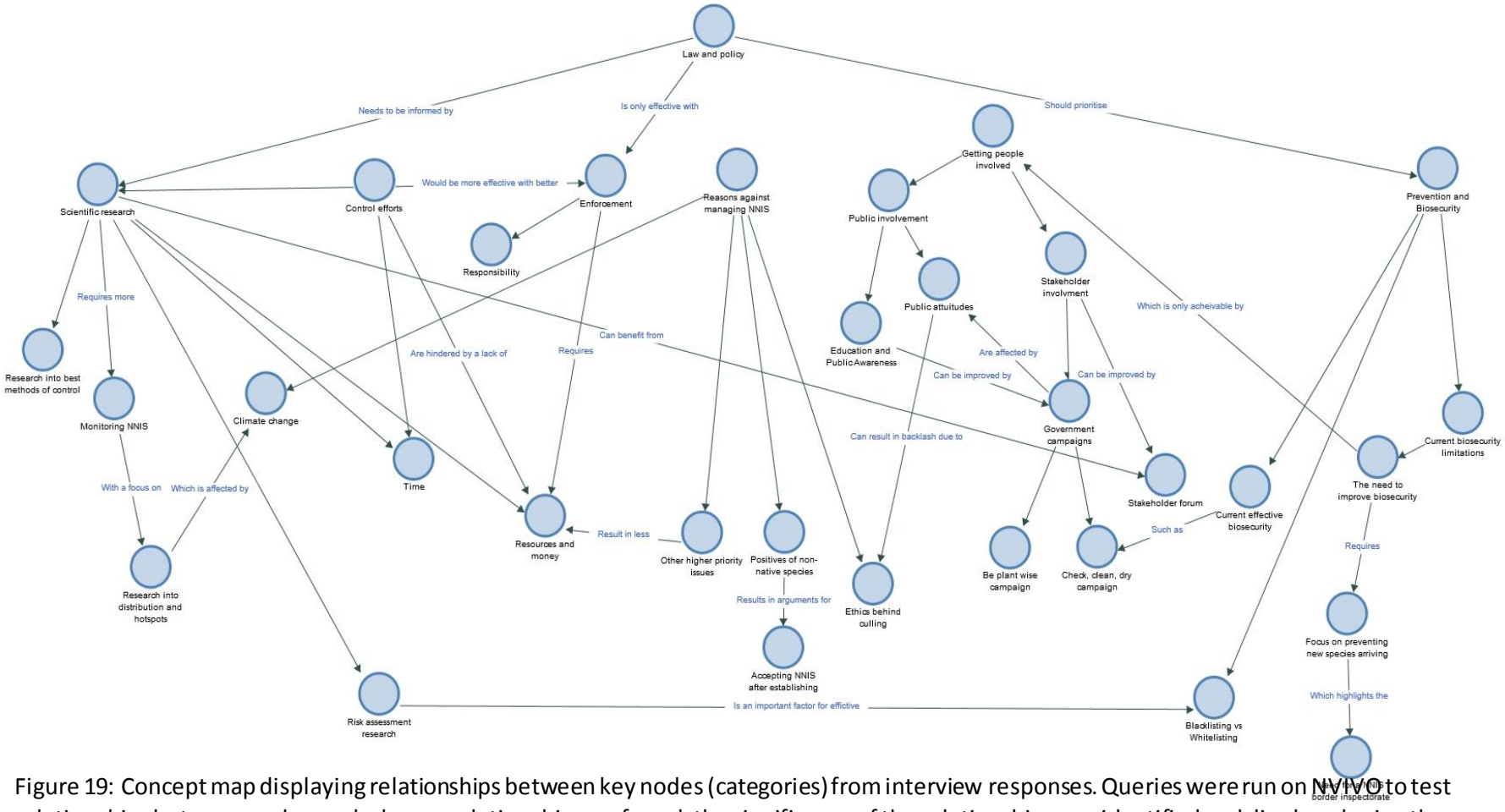


Figure 19: Concept map displaying relationships between key nodes (categories) from interview responses. Queries were run on NVIVO to test relationships between nodes, and where a relationship was found, the significance of the relationships was identified and dis played using the arrows to show how different themes link to one another.

8.4 Biosecurity and prevention:

When asked in the questionnaire how important stakeholders considered biosecurity measures to be in order to achieve effective NNIS management, 27 respondents (69.2%) gave biosecurity the highest score of 10. This was the highest average responses of all five categories, with a mean score of 9.15 across all respondents. This indicates that effective biosecurity is considered by stakeholders as the most important factor in achieving effective NNIS management.

Biosecurity was also one of the key topics discussed in the interviews, returning a total of 38 codes in total. As was evident from the questionnaire responses, in which the majority of respondents scored biosecurity as very important in achieving effective NNIS control, the need to focus on prevention and biosecurity was mentioned several times in interviews and comments (N=9).

When discussing the issues with biosecurity, the main concerns raised were biosecurity at our borders and public awareness and attitude towards biosecurity.

Participant 5 stated: *"I think biosecurity is something that landowners generally don't pay enough attention to"*

and Participant 4 also mentioned convenience as a determining factor for whether people would practice good biosecurity. These responses suggest that as well as associated cost, public attitude is a key aspect when considering biosecurity uptake.

Participant 3 referred more to public education and awareness as a key factor in achieving effective biosecurity, stating that *"anyone can be walking along and causing the spread"*, and several references were made both in the interviews and questionnaire comments of biosecurity and education going *"hand in hand".*

As displayed in Figure 13, 82% of respondents either agreed or strongly agreed that there should be a specific biosecurity inspectorate dedicated to NNIS control at the British borders. This idea was put forward in the 2019 Environmental Audit Committee as something that would assist in better biosecurity at our borders, and the responses demonstrated that this is an opinion shared widely amongst stakeholders to be a good investment going forwards. Responses from the interviews also strongly supported the need for a biosecurity inspectorate, with comments expressing, we have

"Animal Health, plant health, aquatic animal health, and bee health and they all have dedicated inspectorates. And the fact that (Non-Native Invasive Species) don't, you can just see it doesn't make sense, really."

Participants 1 and 7 recommended that if funding was not available for a NNIS inspectorate, then more training on NNIS should be implemented for current inspectorates. This method may be a beneficial alternative to adopting a new NNIS inspectorate, particularly as several respondents expressed their concerns for there not being enough funding available to provide a specialist Non-Native Invasive Species inspectorate.

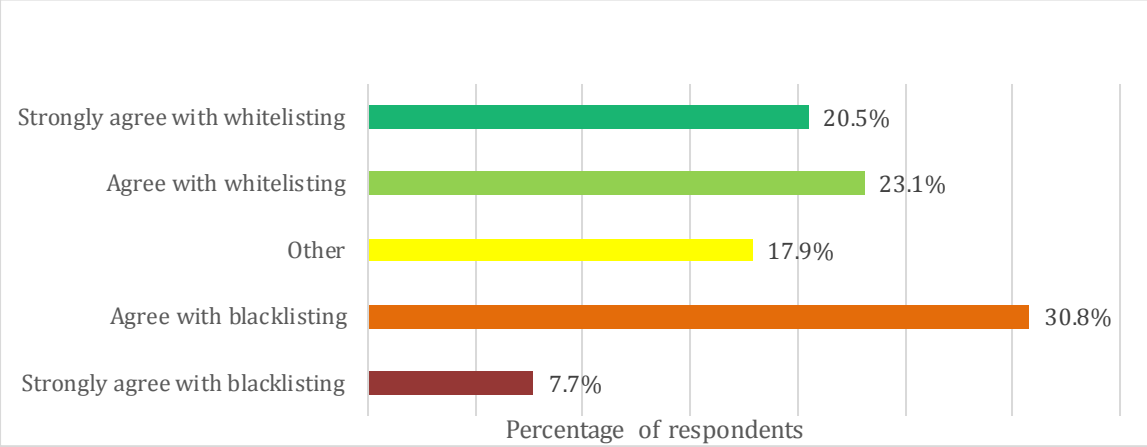


Figure 20: Stakeholders viewpoints on Blacklisting vs Whitelisting

8.5 Blacklisting Vs Whitelisting

There were very mixed responses from stakeholders regarding the blacklisting verses whitelisting approach. Results show that more respondents (43.6%) agreed or strongly agreed with whitelisting, however 17.9% of respondents listed other, with comments indicating uncertainty as to whether blacklisting or whitelisting would be better. Of the 38.5% of respondents that considered the blacklisting approach to be better, most of them selected "agree" as opposed to "disagree", implying that they did not consider blacklisting to be a far superior choice to whitelisting, but still probably a better option for England and Wales.

Respondents were asked to expand on their opinions in the semi-structured interviews and, as with the questionnaire, there were very mixed viewpoints. It was debated by some whether the current Blacklisting approach works for England and Wales.

Participant 5 stated: *"For blacklisting to work, you have to get in early and with most of the problem species that we've got at the moment that that horse has already bolted."*

Other participants also expressed how not enough species are currently blacklisted in England and Wales and action against blacklisted species that have established is not effective enough.
In contrast, most respondents expressed positive attitudes towards a whitelisting approach, with several benefits being highlighted. Respondent 6 stated that:

"The whitelist would take care of all the things that we haven't thought of yet that might be coming."

Indicating that a Whitelisting approach would be beneficial from a preventative perspective, and a further comment from the questionnaires agreed with this idea, saying:

"The potential for 'new' species to arrive is increasing and difficult for government to keep up with, so best to select those we regard as beneficial and keep others out"

Respondent 7 also commented how "*it would make sense to have a whitelist from an ecological point of view"*. However, other responses reflected on the issues associated with adopting a Whitelisting approach, with concerns for *"the backlash"* of *"shift*(ing) *the onus onto the industry or trade to showcase that this species won't have an impact."* (Participant 4) as well as potential lobbying from the horticultural society and causing upset by being too *"restrictive as to what things people are allowed to grow"* (Participant 2).

Participant 7 also expressed how they did not consider it to be *"particularly likely"* that the Whitelisting approach would be adopted, and several participants made comments on the amount of work and time required to change to a whitelist would be a waste and resources could be put to better use in other areas of NNIS management.

One suggestion going forwards was a "happy medium", in which England and Wales adopts some better border restrictions, but *"not going to the extreme of New Zealand"* (Participant 4).

8.6 Getting People Involved

8.6.1 Stakeholder Involvement

Annual Stakeholder Forum

When asked whether they had heard of the Annual Stakeholder Forum, three participants answered "no" (Participant 1, Participant 3, and Participant 8). However, participants who had attended were very positive about it, saying that it is a *"very useful*" event, allowing a variety of Stakeholders to come together and share ideas and different ways of approach NNIS. Participant 7 also stated how the non-native invasive species secretariat attend and *"are very open to stakeholders views and working with stakeholders",* indicating that it is a good opportunity for them to express their opinions on law and policy.

However, Participant 7 also said *"I don't think I've seen evidence of things that have been taken forward from it and directly changed."* Implying that also it is a good place for sharing knowledge and expressing opinions, more action is required from stakeholders, if they want to promote changes to legislation.

Several comments were also made on making the forum more accessible, with Participant 2 *stating "we can never get to it because they always do it in the middle of summer when we're all busy"* and how it is often located too far away in *"Edinburgh, or in York… basically three days out of your life to get there to go to it then come back".*

Participant 8 also highlighted that *"if people knew about it, a lot more people would be interested."*

The interviews highlight how the forum is a useful way of connecting stakeholders and allowing people to communicate their concerns and ideas regarding NNIS, but also how the profile of the Stakeholder Forum needs to be raised, increasing its exposure so that more

stakeholders are aware and will attend, as well as making it accessible, potentially by making the location more centralised or giving people the option of attending virtually.

Government Campaigns

NNIS Government campaigns have been created to raise public awareness and promote good biosecurity practices. Two key campaigns that interviewees were asked about were the "Be plant wise" and the "Check, Clean and Dry" campaigns.

Several respondents responded positively when asked about the campaigns, particularly 'Check, Clean and Dry', with participant 3 commenting that it is *"a pretty simple message"* that *"works well",* and Participant 4 pointed out that it has even been adopted in parts of Europe as a *"best practice*".

Participant 1 was unaware of the campaigns, but felt that they were a positive step:

"I think it's going in the right direction. Definitely. And I think that the problem is getting it out there, kind of wide enough and getting people to actually take the advice up".

Participant 2 had concerns, saying that the handouts for the 'Be plant wise' campaign lacked clarity. However, when they raised this issue, the campaign runners stated they might consider changing it if nobody uses it. However, Participant 2 raised the point *"how will they know if people find it clear or not? People will just ignore it".* This shows an example of stakeholders' views not being taken into account to inform policy.

Participants also agreed that for these campaigns to be a success, it is essential to promote them, particularly to members of the public who will use them and show an invested interest.

"For anything plant wise garden centres will be the first place that you could go to actually spread awareness in the public because those are the people who care. You've got to start getting people who actually care about this sort of thing to be aware of what's happening." (Participant 8).

8.6.2 Public involvement

The involvement of the public in achieving NNIS was considered an essential factor by respondents. 21 (53.8%) of questionnaire respondents scored the importance education and public awareness 10/10, a further four respondents scored it a 9, and nine scored it 8, with only one respondent scoring lower than 7/10.

Nearly all respondents either agreed or strongly agreed with the statement: "Education and public awareness is essential in order to establish effective NNIS control". Figure 10 demonstrated that stakeholders considered education to be an extremely important factor when considering NNIS management, however almost all respondents scored government effectiveness very low (Figure 11). These results suggest that the efforts are not sufficient to undertake the necessary campaigns for raising public awareness and that a greater focus needs to be given to this area.

The engagement of the public was the most frequently discussed topic in the interviews, with the two major sub-topics being education and public awareness which was coded 58 times and public attitudes which was coded 24 times. When discussing education and public

awareness, most responses expressed the need for improvements, with 11 responses directly stating that education surrounding NNIS is currently lacking. This opinion was also supported in the questionnaire, as 86.8% of respondents either agreed or strongly agreed that the government should invest more into NNIS public awareness campaigns (Figure 13).

In the interviews, there were many references to a lack of current education, expressing that "It is still an esoteric subject to most" (Questionnaire comment) and even amongst experts *"There's things that are probably here that we don't even know about"* (Participant 1).

This lack of education was highlighted to be a problem that could lead to unintentional spread of NNIS.

"introductions are quite common in terms of the marine system and a lot of it is through lack of education" (Participant 1)

Participant 3 and 5 addressed the issue of people *"unknowingly spreading it"* with species being
"introduced with not necessarily the best of intentions but a lack of understanding of the potential long term implications." Highlighting the need to ensure the public are more aware of the consequences of their actions that lead to NNIS spread.

Participant 7 also showed scepticism towards current efforts being made towards educating the public, noting that a repeat study in 2018 of a study from 2011 identified that:

"General public's awareness and understanding of invasive species had actually declined in between the two studies"

"but you need to educate people for two reasons I think partly so that people do the right thing without having to wave a big stick and use the law but also to make sure that they are educated about the law because even now, even with all the awareness raising I do locally, lots of my volunteers say "ooh I've never heard of that and didn't know about that" and if they don't know, heaven help the general public" (Participant 2)

Several ideas of how to improve education were suggested, such as *"signage, schools, newspapers"* (Participant 3) and *"having a significant number of people trained up as volunteers* (who) *understand what invasive species are and how to spot them"* (Participant 7).

Participant 5 also emphasised that *"making* (messages) *relevant to people and making them want to share the message"* With content "that people find funny or interesting" could increase exposure and help key educational messages highlighting the risks of NNIS and promoting good biosecurity practices reach more people.

Participant 8 also highlighted the importance of education to get people to help in NNIS management:

"A lot of the time people are interested in and they care, but they just don't know. They have no idea what's happening."

However, public attitudes towards NNIS were also explored and not everyone agreed that they were always positive, with more participants sharing experiences of negative public attitudes than positive.

Key issues highlighted with attitudes were people included the effort required to prevent

NNIS spread. Participant 1 commented:

"It's easy just to go out there on the water, do something and then not necessarily think about washing things down, drying them properly"

Participant 6 commented on how *"the public generally have fatigue"* when it comes to reporting and showing interest in NNIS.

Participant 2 had experienced more mixed attitudes amongst the public, with several positive comments:

"Some landowners completely voluntarily give us donations (for NNIS control), *which is really nice"*

"(Some) *people are really, really grateful you know like a lady yesterday, she said, "ooh the cakes are for your volunteers in the porch"'"*

However, Participant 2 had also had experience of negative respondents who showed little appreciation towards control efforts:

"Some people who- they give you permission to do control work and it's almost as if they're doing us a favour by giving us permission to do it on their land."

Several respondents also highlighted issues with respondents who refused to change their views, as explained by Participant 4:

"Sometimes you can have a conversation with someone and you present all the evidence, you're very objective and are putting across what the issues are why it has to be done. And they can very much say, like I can take that on board. I understand. However, I'm still against this."

Participant 8 stated that *"You can't start with the adults now because they're too entrenched in their ideals"*, again expressing the need to focus education campaigns in schools on younger generations.

8.7 Law and Policy

Results from the questionnaire revealed that respondents gave mean scores for law and policy as 8.82 for importance, but only 4.77 for how effectively they considered it to be in England and Wales.

In the interviews, several comments were made regarding limitations and recommendations.

Participant 4 addressed the need to update NNIS lists (i.e. Schedule 9 and the List of Species or Special Concern) more regularly, stating *"we need to be able to review something yearly so you can respond to threats."*

Participant 7 *"I'd say in terms of the legislation, the EU regulation was sort of converted into domestic law and post Brexit there. We do still have concerns about the way that that's going to operate, because the proposal is essentially to replace like the scientific forum,*

made up of experts across the entire EU, with like two experts in the non-native invasive species secretariat."

One of the biggest concerns addressed by stakeholders in interviews about law and policy was how complicated and difficult it is to understand:

Participant 2: *"I think in terms of the law generally it has got so confusing for everybody."*

Participant 4 *"It's like, well, what does it mean for me? How does it impact me in my activity? So yeah, it probably does need to be simplified into a better document somehow that's easy to understand because law text, I mean I struggle sometime to understand what it means."*

Participant 6: *"So you can have any number of policies and strategies and stuff, but without your thoughts on the ground and powers on the ground to tackle this stuff, it's not going to get any better."*

This highlighted the view that no matter how good law and policy in England and Wales is in practice, if enforcement and regulation is not effective, then it ultimately will not be effective in preventing and controlling NNIS spread.

8.8 Responsibility and Enforcement

When asked about the effectiveness of enforcement in the interviews, most of the responses were negative, Participant 4 said enforcement *is "really lacking"*, Participant 5 commented on how they *"don't know how much better enforcement has really got at the moment"* and Participant 8 stated that *"there's just no incentive or threat. There's nothing."*

There were also several comments highlighting the uncertainty of who is responsible for enforcing and how to go about it. Participant 6 explained:

"People would come to us and say, "I have seen this invasive species or I have this invasive species on my land. What should be done about it? Or can you do something about it? And there's been, in most cases, no route to doing anything."

Another respondent also conveyed the issues they had in using the Species Control Order:

"I spoke to DEFRA about it, just informally, and they said, "Well, don't try that. Because we know that the government doesn't really want to use species control orders for widely established plants" they only want to use them for things which have just come into the country and I felt a bit crestfallen."

These statements indicated that despite there being the legislation in place, very little action is actually being taken at a grass-roots level with regards to enforcement, and illegal actions *"for example the online trade* (of NNIS)" is happening without people being stopped or prosecuted (Participant 4).

Participant 3, however, highlighted the issues of enforcement out on site, commenting:

"anyone can be walking along and cause the spread… how to you police that? That's impossible"

They went on to say how education has to come first, saying that *"People know need to know that they're doing something wrong"* before it is fair to enforce against them.

One idea posed to respondents in the questionnaire was to create a separate, funded authority specific to NNIS, in charge of enforcement powers. The majority of respondents (72.9%) agreed that a consistently funded regulatory boy would be a good step going forward regarding NNIS control, however, 18.9% of respondents did not agree that this would be a good idea (Figure 13).

One concern for this idea was whether a single body could effectively cover all the different types of species as effectively as having different representatives for different habitats, such as marine, fluvial, and terrestrial. It was also suggested to have bodies that covered locations across England and Wales, rather than looking at the area as a whole, as different parts of England and Wales were affected by different NNIS, and locational factors were important to consider when planning control programmes.

A comment from the questionnaire also highlighted that *"The 2019 enforcement and permitting order is still very new but does offer a process for enforcement."* Suggesting that enforcement measures may be more effective going forwards.

8.9 Control Efforts

When applied correctly, control efforts can achieve *"good quality habitats"* and *"can see the improvements in things"* (Participant 2).

Participant 8 also highlighted that control programmes can be aided by public participation

"You've got members of the public who in their own time with their own money and their own resources are going to go out and try to control this species."

However, considerations have to be made to ensure control is effective, as cautioned by Participant 4:

"Management is important but needs to be done at the right scale, have the right amount of money dedicated to it, and be coordinated and strategic."

Many comments also highlighted how control programmes, particularly of widely established species can be a waste of resources, impressing the importance of planning and assessing the effectiveness of a control programme to ensure it will be effective and make a significant positive impact otherwise you will end up *"fighting a losing battle and the amount of time and effort money that would go into that I would imagine enormous" (Participant 3).*

The scale of eradication and environment in which control is being undertaken is also a factor to consider, with Participant 1 explaining:

"In the marine environment, it's impossible. You never will (achieve control) *once you've got an invasive species established. It's just you're not going to eradicate it. It's an open system. It's, yeah. You'd just be wasting your time really and effort."*

The resources available are another key consideration, with Participant 5 stating:

"For most of the existing problem species we've got, unless you're prepared to throw huge amounts of money at it, you're not going to sort them out."

8.10 Potential Limiting Factors

8.10.1 Resources, money, and time

Resources, money, and time were frequently brought up in interviews as pivotal factors to consider for successful NNIS management in England and Wales.

Several comments stated how resources and money were lacking, with Participant 1 stating: *"I think, lack of funding and education is maybe the problem"* and Participant 4 commented on there being *"a complete imbalance of resourcing"* when it comes to NNIS compared to factors such *as "animal and plant and fish and bee health".*

Participant 1 also implied how, due to not having as great an economic weighting as other environmental issues, NNIS was not as sufficiently funded as other factors:

"So in terms of environmental considerations for a port, a lot of what they're spending their money on is maybe like reduced emissions so air quality emissions, rather than non-native species. They don't necessarily see non-native species as a business threat."

However, there were also positive remarks regarding money and resources. Participant 2 commented:

"Well, we've been really lucky because apart from one year when we didn't have quite enough funding, I was able to cover the cost of all the control work through the grant aid that we get. For 10-11 years we've had grants from all sorts of different organizations."

Indicating that if resources are used effectively, they can go a long way in NNIS management. Participant 5 also considered *"the more we raise the profile* (of NNIS), *the more you're likely to get funding to follow".*

If more funding was to be allocated toward NNIS control, respondents were asked whether the Government should create an initiative for landowners, to fund and assist in the removal of the NNIS on private land, provided they report the species immediately and are cooperative during removal operations. Questionnaire results showed that most stakeholders strongly supported this idea (61.5%), a further 11 (28.2%) agreed, it was a good idea, 3 respondents (7.7%) were unsure, selection "neither agree nor disagree" and only one respondent strongly disagreed (Figure 13).

When asked about this idea in interviews, however, there were a few concerns raised by Participants. Participant 3 commented:

"Helping them fund and manage the removal, that is difficult... That can cost a lot of money. It's a lot of time. It's their projects that you have to manage and their in their overtime, because it doesn't just happen. "

It is clear that serious consideration as to where to distribute funding is necessary. Participant 2 cautioned giving landowners money directly to control NNIS on their land, due to an experience with a landowner who was given funding, explaining:

"For some years he was taking the stewardship money high level stewardship money and not using it for what it was intended for "

Instead of giving money directly to landowners, Participant 2 instead expressed how local action groups would be the most cost-effective use of money and resources:

"My hope would be that that money could be channelled to local action groups like ours, where you've got local people who know the landowners, they know what's out there on the ground, what needs tackling, they know what the national priorities are in terms of which species need to be tackled and they can take catchment wide approach."

8.10.2 Other higher priorities

One concern for a lack in funding was that the government does not consider NNIS high on the priority list, and, particularly in the current COVID-19 situation, funding for NNIS is not considered an important area. Participant 1 commented:

"There was a phase where there was quite a few non-native species projects going on and money directed towards it, but it seems to have kind of dropped off the radar, a little bit. "

Participant 3 also supported this notion, stating:

"Everything needs money, and this clearly would need money and investment in it. But like we said earlier, is that going to be a priority is that where the government are going to put money into, especially at the moment."

8.11 Ethics Behind Culling

The ethics behind lethal control programmes was another key concern. From the literature research, this topic was anticipated to have mixed responses. Although most of the stakeholders considered the protection of native species to be of greater importance than concerns behind the ethics behind culling, with 37.8% of respondents strongly agreeing and 24.3% agreeing, 29.7% of the respondents were undecided, choosing "neither agree nor disagree".

Interview responses reflected these mixed views regarding culling, with several participants referring to culling as a "necessary evil":

*"It's a balancing act. And often the brutal methods are cheaper and quicker." (*Participant 5)

"If we are going to be successful in eradication, then you got to bite the bullet sometimes literally." (Participant 2)

However, participants also expressed how *"It's a very, very contentious issue"* (Participant 2), expressing concerns over the public being *"resistant to the culling of animals"* (Participant 6).

Several participants also agreed that where lethal control could was necessary, *"It should be done as humanely as possible."* (Participant 2), and when it could be replaced with other methods (e.g. sterilisation), it should be.

"Rather than lethal control, if you can minimize the harm to that species then that should be something that should be considered." (Participant 4)

It was also noted from the participants responses, that ethical issues are more of a concern with animal (and particularly mammal) species; control of invasive plant species did not raise ethical concerns in the same way, and species such as the grey squirrel were the most contentious.

8.12 Case Study Species

During the semi-structured interviews, respondents were asked questions surrounding the three case study species: Grey squirrel, signal crayfish and Japanese Knotweed. They were also asked to highlight any other problematic NNIS that they had had personally encountered. Table 10 lists the other NNIS that were mentioned, the key points made, and which respondents had talked about each species.

Table 10: Summary of non-case study NNIS discussed in semi-structured interviews

Species Mentioned	**Points made**	**Respondent(s)**
Sargassum Mutica	Smothers native populations	1
Wakami	Out competes native kelp	1
Slipper Limpets	Spreads across habitats	1
Sea Squirts	Not causing any harm	1
Himalayan Balsam	Late season bloomer for bees	2, 3 & 6
New Zealand Pygmyweed	Spreads fast and difficult and expensive to control	2, 4 & 6
Giant Hogweed	Human health	3
Zander	Conflict from anglers wanting to fish it	4
Topmouth Gudgeon	Rotenone is only control method, impacts anglers, causing conflict	4
Zebra Mussel	Impact on water industry, blocking pipes	4 & 5
Floating Pennywort	Widely distributed	4 & 7
Skunk Cabbage	Nobody controlling spread	6
Killer Shrimp	Hugely problematic where they have established	7
Indian Red Necked Parakeet	First established in London and spreading very rapidly. Diverse and aggressive bird	8

8.12.1 Grey Squirrel

When asked about grey squirrels in England and Wales, the main topic of conversation was the social implications. Comments were made regarding the positive association the public have with them:

"Grey squirrel is an interesting one because obviously people see them and they're kind of cute and fluffy" (Participant 1)

"They're so tame and so people's idea of them of being cute. They don't know about red squirrels, they're not aware of them and they just know this one that's there and they get very attached to it. And so I think when you're thinking of social, actually then it can be seen as a benefit because if they weren't their then the enjoyment maybe of those places might not be the same." (Participant 4)

"With grey squirrel groups, it's that thing of: Well, why it's here? So for example you might have it in London red squirrels are unlikely to return. So what is the benefit long term of managing the species?" (Participant 2)

Participant 7 also highlighted how you can *get "real pushback from the animal welfare movement against* (control)" and again, the argument against eradication in urbanised areas was mentioned:

"Particularly in urban areas where there aren't any red squirrels and grey squirrels are so populous, it's not going to have a huge conservation impact anyway."

However, not everyone is a fan of grey squirrels, as *"grey squirrels cause a lot of upset for the forestry industry"* (Participant 8), due to them eating seeds and shoots off trees. Because of these varying opinions, control programmes can often cause *"divides in communities"* (Participant 8), with action groups protesting culling, whilst others consider them pests.

8.12.2 Signal Crayfish

In stark comparison to grey squirrels, Participant 1 addressed how little the public were aware of signal crayfish and their impacts, speculating that *"people probably don't even know what a crayfish is".* With Participant 8 observing how it *"does not get enough traction* (because) *it's not cute and fluffy enough."* However, Participant 4 disagreed, stating:

"Basically every conversation I have, if someone is aware of invasive species… Japanese knotweed or signal crayfish as the two that they state."

With regards to impacts, the general consensus was that signal crayfish caused a number of detrimental impacts. Participant 4 expressed how *"Signal crayfish obviously, they have huge economic impacts, as well as environmental"*

Other conversations relating to control of signal crayfish highlighted the difficulties faced as,

"it's very easy for someone to mistakenly allow them to recolonised. Particularly because with signal crayfish because they can travel across, across significant distances to reach other watercourses." (Participant 5).

Once again this highlighted the need to have well-coordinated measures in place for control to be effective.

With regards to policy, it was commented that signal crayfish was a complicated species, with Participant 7 explaining:

"So it was treated quite differently in like policy terms in the consultation and they've come up with a new way of sort of- they're called exclusion and containment zones. So you're not allowed to trap any signal crayfish in exclusions zones, licensed people are allowed to trap signal crayfish in containment zones, provided that they are dispatched on the spot and then processed in a facility. So there's been like a change of policy there." This policy change may help make on-sight signal crayfish control programmes easier to carry out.

However, other policy changes regarding exporting signal crayfish have been exposed to be highly influenced by businesses and economic factors:

"The initial policy was that from the beginning of 2020, live export of signal crayfish would no longer be legal, and then two or three weeks later they issued an amendment revision to that policy saying that live export would be out for a two year transition period. Which was pretty much solely from the intervention of these two big businesses." (Participant 7)

8.12.3 Japanese Knotweed

When asked about the Japanese Knotweed, Participants highlighted the economic implications to do with mortgages and high costs associated with control.

Participant 2 even commented on how they have observed using the negative associations of Japanese Knotweed and contractors *"preying on* (landowners') *fears"* to overcharge landowners for control programmes, with *"households unwittingly ending up having to spend a lot more money than they need to".*

Comments were also made regarding the environmental impacts it has had:

"it's just completely out competing, everything else" (Participant 2)

Public awareness of Japanese Knotweed was stated as being good, with Participant 5 even saying *"it's the one the public have got the most knowledge and understanding of"* however, they also stated that *"even amongst landowners, the understanding of the implications of it and how to control it very poor"*. Showing a need for clarity and better education surrounding control measures. A comment from the questionnaires suggested how media exposure is one effective way of increasing exposure and improving education:

"Social factors play their part - for example media stories around Japanese knotweed which raises its profile dramatically compared to aquatic INNS which can often pose more of a financial and natural capital impact."

9 Discussion

To effectively control NNIS, it is clear that law and policy must consider biosecurity and prevention, public involvement, scientific research into effective control efforts and enforcement. It is also evident that there are areas for improvement in all these factors, which could be changed to improve the prevention and control of NNIS in England and Wales. These ideas are discussed below.

9.1 Achieving Effective Prevention and Biosecurity

The general consensus set forward by key policy, including the CBD, GB Invasive Non-Native Species Strategy, and 25 Year Plan that prevention and early intervention is the best approach with regards to stopping NNIS spread was also widely supported by stakeholders, with respondents scoring biosecurity and prevention as the most important factor in achieving NNIS management (9.15 (SD = 1.6). However, stakeholders also addressed the need to improve biosecurity measures.

With regards to internal biosecurity, the uptake of good biosecurity practices is essential. In aquatic environments the "check, clean and dry" has been rolled out as a Government campaign to promote good biosecurity practices. However, studies identified varying reliability of this technique (Anderson et al. 2015; Shannon et al. 2018). Furthermore, studies have demonstrated that the uptake of good biosecurity practices is still poor (Anderson et al. 2014; Foster et al. 2016). This lack of education surrounding biosecurity was also addressed by stakeholders in interviews. However, participants also highlighted that public attitude was also an important factor to consider, with several of them having experienced difficulties to do with public attitudes towards biosecurity. Attitude was also indicated as an issue in literature (Foster et al. 2016). However, negative attitudes are often associated with the cost of practising good biosecurity rather than a lack of care (Foster et al. 2016; Vye et al. 2020). Investing resources into holding tanks for cleaning hulls and 'check, clean and dry' cleaning facilities could help address these negative attitudes and encourage more people to take up better biosecurity practices.

However, it was also recognised that for some stakeholders, good biosecurity practices were only considered when NNIS directly impacted their businesses (Foster et al. 2016; Suttcliffe et al. 2017). In this instance, it may be necessary to change biosecurity legislation, implementing a Biosecurity Act as seen in Australia as a legal incentive to undertake better biosecurity (Shannon et al. 2020).

One key improvement to biosecurity, which was addressed in the House of Commons Environmental Audit Committee (2019) would be to appoint a NNIS biosecurity border inspectorate. Stakeholders highlighted how animal, plant, fish, and bee health all currently have inspectorates and are given disproportionate resources compared to NNIS, despite the threat that NNIS poses. This study therefore recommends that border resources are reviewed, and an inspectorate is appointed if possible. Stakeholders also recommended that if funding were not available for a new NNIS inspectorate, current border inspectorates could be trained to recognise and report NNIS as a cheaper alternative.

9.2 Blacklisting vs Whitelisting

As with the systemic review, there was a lot of uncertainty from respondents as to whether England and Wales should adopt the whitelisting approach (as suggesting in Environmental Audit Committee (2019)) or maintain the current blacklisting approach.

The benefits of whitelisting were that it would encompass all NNIS, removing the risk of species being forgotten on a blacklist (Dehnen-Schmutz 2011; Garcia-de-Lomas and Vila 2015). However, stakeholders also addressed the potential backlash that would occur,

particularly from the horticultural society, if England and Wales were to adopt a whitelist, as this would ban non-native species that were previously traded, restricting what people can grow and causing potential financial implications for businesses.

Although further research is recommended regarding the best option for England and Wales, results from this study indicate a middle ground option may be the best, approach, by adding species to the blacklist more regularly, and also looking into adding a "greylist" to policy of species that have the potential to be a risk and should therefore be assessed before being permitted across the borders (Garcia-de-Lomas and Vila 2015).

Risk assessments are an important tool to use when determining which species to blacklist (Garcia-de-Lomas and Vila 2015). These can be improved through sharing knowledge on an international level and applying key information from DAISIE to help inform decisions on species (Collier 2018). However, several comments from stakeholders highlighted that policy gives a focus to economic impacts of NNIS, and highlighted the need to focus control more on preventing ecological damage (e.g. targeting grey squirrel control programmes in areas with red squirrel populations). Ecological impacts are important to consider and should be a key focus of risk assessments to help prevent biodiversity loss and ecological damage through NNIS introductions (Dickey et al. 2018).

9.3 Control Efforts

Many factors should be assessed before undertaking control measures for any NNIS. Ensuring that methods for control are backed by the most up to date scientific studies is an essential factor, as studies have highlighted control programmes that have been ineffective due to a lack of research into NNIS control methods, as demonstrated in the case of Signal Crayfish with baited traps being ineffectively used for control in rivers (Green et al. 2018).

The grey squirrel and signal crayfish case studies demonstrated that density dependency factors can negate the effects of management and should therefore also be considered to assess whether a management project will be successful and worth investing resources into (Parkyn et al. 2002; Lawton and Rochford 2007; Freeman and Turnball 2010; RSPCA 2015). It was also expressed in interviews that a coordinated and strategic approach to control programmes, with a clear and achievable goal is important, and not to just carry out *"management for the sake of management".* Participants also cautioned that management programmes, particularly of widely established species can end up being a waste of time, money and resources.

Japanese Knotweed also highlighted several steps that are sometimes required in achieving NNIS control, making it difficult for landowners to undergo management (Environment Agency 2016). Participants in the interview frequently addressed how if efforts to control NNIS were too great, many people would not bother. Whilst undertaking the correct procedures to control Japanese Knotweed is important, the complexity of these steps and high associated cost may act as a deterrent to landowners.

Government incentives, such as providing funding to landowners to assist in removal of NNIS could encourage management (DEFRA 2020). However, the case of a landowner receiving stewardship money and not using it to undertake control works (Participant 2), suggests that

this method is flawed. Instead it is recommended that the government invests money and resources into local action groups that focus on NNIS control. Several stakeholders highlighted how these action groups have achieved successful control at a grass-roots level. These local action groups involve volunteers in management works, which makes them a more cost-effective option, and also helps to spread positive awareness of NNIS management and its benefits (Pagès et al. 2019).

9.4 Ethics Behind Culling

The ethics behind NNIS control was identified in the literature research to be a contentious area, particularly for mammal species, such as the grey squirrel. The literature review identified studies arguing that NNIS should be allowed to establish and that extermination programmes are morally wrong. Some studies also addressed the difficulties of gaining public support for culling programmes, therefore, varied responses for this question were expected (Dunn et al. 2018). However, the target audience for the questionnaire was stakeholders with a reasonable level of knowledge in the field of NNIS, therefore they understand the negative impacts caused by NNIS, which may explain why the majority still agreed that protecting native species took precedence over the ethical concerns for NNIS welfare.

The case study of the grey squirrel demonstrated issues that can arise due to backlash from the public questioning the morality of culling NNIS (Dunn et al. 2018). Interview participants also highlighted how it is a contentious issue that received a lot of backlash from the public, particularly for animal and mammal species (e.g. the grey squirrel). However, participants also stated that in certain cases, culling was necessary in achieving NNIS controlling, but argued that where possible, extermination problems should be avoided. Resources instead could be distributed more into methods such as sterilisation of species. However, concerns of these methods being costly and time consuming compared to culling were raised. If more ethical approaches are to be used more in the future of NNIS control, it will be important to factor in the extra resources and time required.

The negative public attitudes are something which should always be considered in NNIS control programmes, particularly when increasing the profile of NNIS management to raise public awareness, with participants from the questionnaire cautioning that an increase in public awareness may also increase backlash against lethal methods of NNIS control. However, educating public on the threats associated with NNIS and the harm they can cause to native biodiversity can help gain more support for control and eradication programmes (Newson et al. 2009). In order to minimise the risk of public backlash and gain support, educations programmes should therefore put a strong emphasis of the detrimental impacts of NNIS and the benefits of managing their spread.

9.5 Getting people involved

This study clearly indicates that stakeholders and getting both stakeholders and the public involved is crucial in achieving effective NNIS management, both through informing law and policy and in ensuring effective control and prevention measures (DEFRA 2003; Bayliss et al. 2013; Reed and Kurzon 2015; Novoa et al. 2017; Eriksson et al. 2018; Kapitza et al. 2019).

To incorporate stakeholders' concerns and ideas when making decisions regarding NNIS legislation, the Stakeholder Forum was initiated in 2004. However, stakeholders raised concerns that their viewpoints were still not being considered in policy-making decisions (Great Britain Non-native Species Secretariat 2015). Participants from the interviews expressed that although it was a good place to form communications with other stakeholders and share views on NNIS, there was little to no evidence that points made by stakeholders in these forums were actually being used to inform policy. Furthermore, the difficulties of attending (due to location and time of year) were noted as issues, and several respondents had not heard of the forum, highlighting the need to raise awareness of the Stakeholder Forum and make it more accessible, potentially through having virtual/online options of attendance. Evidence that stakeholders' recommendations are being used to inform policy is also an important step that needs to be considered by NNIS policymakers.

One hugely beneficial step towards controlling NNIS spread would be to improve public education and awareness, as current understanding of even the highest profile NNIS in England and Wales is poor (Gozlan et al. 2013; Robinson et al. 2016; Eriksson et al. 2018). Responses from stakeholders even suggested that education of NNIS has decreased in recent years, emphasising the need to focus more attention on campaigns promoting the importance of preventing NNIS spread and the ways in which public can respond to help.

To achieve this, stakeholders recommended that more focus be put into government campaigns such as 'Check Clean and Dry" and 'Be Plant Wise'. Although these campaigns have shown some levels of success, with 'Check, Clean and Dry' being adopted in other countries, more could still be done to improve clarity and give the campaigns greater exposure to the public. Ensuring campaigns are supported by science to be best possible practice is also key, and they should be regularly assessed to ensure they are up to date with findings from scientific studies (Anderson et al. 2015; Shannon et al. 2018).

Other suggestions for improving public awareness included creating signage in high exposure locations such as parks to alert the public of the risks associated with NNIS spread and how to adopt good biosecurity practices. Including biosecurity and the risks of NNIS into the school curriculum was also suggested, which could be a hugely effective tool as increasing education in environmental issues has been shown to increase levels of concern and increase in positive attitudes towards making positive environmental changes (Taber and Taylor 2009).

However, improving public education is not the only factor to consider. The attitudes of people towards NNIS control were also important to consider, with the study demonstrating public attitudes to be negative in many cases. As mentioned for the government campaigns, they will only be effective if the public show a willingness to follow the advice given and take responsibility for their actions (Foster et al. 2016). Although stakeholders expressed difficulties in changing the minds of public and encouraging more positive attitudes, it was recommended that educating younger generations and promoting positive attitudes towards NNIS at a young age could improve public opinions and encourage more participation in helping prevent NNIS spread in the future.

9.6 Enforcement

This study identifies severe limitations in current enforcement measures, with stakeholders from questionnaires and interviews commenting on how lacking enforcement is throughout England and Wales, implying that there is no incentive or threat for people to follow current legislation.

Enforcement responsibility lies with several different authorities, which can lead to confusion if different information is given by different authorities (Shannon et al. 2020). The idea of having a consistently funded separate regulatory body specifically focussed on invasive alien species to help develop more focused enforcement of NNIS was put forward as a potential idea to stakeholders. While most respondents agreed with this idea, with only 18.9% of respondents disagreeing with this idea in questionnaires, several concerns were raised in interviews. The main concerns with this idea was whether a single body would be able to effectively cover a wide range of habitats and that a single body would be too focussed on enforcement in England and Wales as a whole rather than addressing more local factors. Considering these factors, it is instead advised that effective communication between current enforcement authorities is improved to ensure advice to public is consistent. More clarity into which enforcement authorities to contact in different situations should also be addressed.

Although legislation for enforcing against NNIS has seen updates and improvements over the years, the application of these laws can be complicated. For example, Species Control Orders were created in 2015 as an enforcement device to issue mandatory control of NNIS when landowners are non-compliant. However, when a stakeholder attempted to enforce using a Species Control Order, they were unable to gain permission to issue one, being told by DEFRA that the government does not want these Orders to be used for widely established species (Participant 2). The fact that this order is not being used to enforce on the most widely established NNIS (DEFRA 2015), shows the limited use of Species Control Orders and relatively low impact they will have in controlling NNIS in England and Wales. It is recommended that this order is reviewed and that using Species Control Orders for high profile species is considered on a case-by-case basis, particularly in areas where control efforts would be beneficial.

It is still too early to assess the effectiveness of the 2019 enforcement and permitting order, however, it is hoped that this new legislation is a positive improvement in achieving better NNIS enforcement.

Without effective enforcement measures in place, NNIS legislation holds very little weight, meaning its ability to assist in preventing and controlling NNIS spread is limited.

9.7 Recommendations for Improving Law and Policy

From this study, several improvements are recommended to improve law and policy in England and Wales to assist in achieving effective NNIS control.

The first of these is to creating a Biosecurity Act, as seen in Australia. From investigating the uptake of current biosecurity practices, it was identified that very few people carried out effective biosecurity protocol, particularly in aquatic environments (Foster et al. 2016; Suttcliffe et al. 2017). A Biosecurity Act would therefore be a useful enforcement tool, providing a legal incentive for people to be more careful and biosecure (Shannon et al. 2020).

Investing more into political campaigns, such as 'Check, Clean and Dry and 'Be plant Wise' is also a recommendation, as well as investing more money into campaigns to raise awareness of NNIS. A social media campaign is also recommended, as well as resources into creating more signage in parks and key public areas to educate people and expose them to the impacts of NNIS and the benefits of removing them, as well as detailing how people can help in preventing their spread.

It was also recommended that lists of NNIS (i.e. Schedule 9 and the List of Species of Special Concern) need to be regularly updated and take into account recommendations from stakeholders. These lists should also be scientifically informed through detailed risk assessments that incorporate all potential impacts and apply knowledge from other jurisdications (Collier 2018; Dickey et al. 2018).

Any new policy should always incorporate knowledge from both scientific researchers and stakeholders, to ensure it is as effective as possible (DEFRA 2020). When planning national management programmes, carefully researched Species Distribution Models (SDM) should also be used to predict NNIS hotspots and help assess the most effective methods of control (Jones et al. 2013; Gallardo et al. 2015; Whomersley 2015; Polaina et al. 2020).

A key point made by stakeholders, was the need to improve clarity, and make legislation easier to understand. Current law and policy surrounding NNIS is very complex, making it difficult for stakeholders and the public to interpret. People who are aware of the law and policy are likely to adhere to it (Robinson et al. 2017), however, interviews with stakeholders revealed that from their experience, knowledge and understanding of NNIS law and policy was poor. It is recommended that, where possible, NNIS legislation could be simplified (provided this does not negatively impact the constitution). It is also advised that the Government releases a clear and concise document (or code of practice), detailing the legislation associated with NNIS and how this related to the public.

10 Conclusion

This study identified several key factors that influence the effectiveness of law and policy in achieving effective NNIS control in England and Wales: Biosecurity and prevention, getting people involved, scientific research into effective control efforts and enforcement. Three high profile case study species; grey squirrel, signal crayfish and Japanese Knotweed were investigated to determine how effective these factors and law and policy were when applied to specific NNIS. The views of stakeholders were also determined through questionnaires and semi-structured interviews, with the following conclusions being made from the results.

Current public awareness of NNIS is poor, highlighting the need for the government to invest more into education campaigns such as promoting 'Check, Clean and Dry' and 'Be Plant Wise', but also funding more media campaigns, creating signage in parks, and including education of NNIS in schools. Involving the public in NNIS volunteer control and monitoring work can be cost-effective and gain public support towards NNIS management. It is therefore advised that the government invests in local action groups (e.g. wildlife trusts) that work with volunteers to manage NNIS effectively. Better education can in turn help improve biosecurity, with more people practicing better biosecurity protocol. Where public attitudes cause limitations in biosecurity, the implementation of a Biosecurity Act could be an effective tool in providing legal incentive to follow good biosecurity protocol. The main recommendation for improving prevention of NNIS entering England and Wales is to employ a NNIS biosecurity inspectorate to improve border control. It was highlighted that scientific research into areas such as risk assessments and species distribution is a key component in aiding preventative policy, and extensive research into effective control measures is crucial to ensuring NNIS control programmes are an effective use of resources. Enforcement was determined to be the least effective area currently, with very little evidence of law and policy being enforced to prevent illegal NNIS spread. It is therefore crucial that enforcement efforts are improved to achieve effective NNIS management and ensure law and policy is implemented in England and Wales.

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Invasive Alien Species (Enforcement and Permitting) Order (2019)
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Network Rail Infrastructure Ltd v Williams & Anor (2018) EWCA 1514 (Civ)

Schedule 9 of the Wildlife and Countryside Act (1981)
Available from: https://www.legislation.gov.uk/ukpga/1981/69/schedule/9

Water Framework Directive 2000/60/EC

Weeds Act (1959)

Appendices

Appendix 1: Participant Information Sheet

Participant Information Sheet

The title of the research project

An analysis of the effectiveness of law and policy in assisting in control of non-native invasive species in Great Britain by use of case study species and questionnaires to stakeholders.

Invitation to take part

You are being invited to take part in a research project. Before you decide it is important for you to understand why the research is being done and what it will involve. Please take time to read the following information carefully and discuss it with others if you wish. Take time to decide whether or not you wish to take part.

What is the purpose of the project?

Non-Native Invasive Species (NNIS) have been recognised globally as a major threat to biodiversity. Being an island nation with longstanding global trading links, Britain is particularly susceptible to the threats that NNIS pose. Although current law and policy identify these threats and scientific research has explored the impacts and methods for control of many NNIS, gaps in knowledge exist. As such, a clear cohesion between science and law is currently a limitation.

This study aims to explore the views of stakeholders directly impacted by NNIS using questionnaires. By taking into account these important views, the study will identify gaps and challenges in current NNIS law and policy and use this information to suggest alternative measures that could be incorporated in England and Wales to better control NNIS in the future.

Why have I been chosen?

It was considered important to aim for respondents with a knowledge and understanding of NNIS, so they can reflect on their own experiences with tackling the issues created by NNIS. This study has selected respondents from a variety of backgrounds to ensure the viewpoints of different organisations and fields of work are represented. Participants have been carefully selected given this background, therefore there are only a few respondents who meet the necessary criteria. Participation is entirely voluntary, however, should you choose to participate, your contribution will be extremely beneficial to this study and greatly appreciated.

Do I have to take part?

It is up to you to decide whether or not to take part. If you do decide to take part, you will be given this information sheet to keep and be asked to sign the participant agreement form. We want you to understand what participation involves, before you make a decision on whether to participate.

If you or any family member have an on-going relationship with BU or the research team, e.g. as a member of staff, as student or other service user, your decision on whether to take part will not affect this relationship in any way.

Can I change my mind about taking part?

The questionnaire is anonomised, therefore it will not be possible to remove data once submitted, however, should you wish to discontinue with the questionnaire, you may stop at any time and any non-submitted answers will not be recorded.

If I change my mind, what happens to my information?

After you decide to withdraw from the study, we will not collect any further information from or about you. Only information that has already been submitted by you will be used but not identifiable as your responses.

What would taking part involve?

If you choose to take part, participants are asked to answer a short questionnaire that should take no longer than 10-15 minutes to complete. Respondents will also be given the option to participate in a semi-structured informal interview process should they so choose.

What are the advantages and possible disadvantages or risks of taking part?

Whilst there are no immediate benefits to you participating in the project, it is hoped that this work will create a valuable insight into the opinions of stakeholders regarding Non-Native Invasive Species in Britain. This study aims to highlight current issues with NNIS control and express how law and policy can be improved to ensure better control measures for NNIS in Britain.

We do not anticipate any risks in taking part and will ensure that necessary measures are taken to protect the identity of participants. Any data collected from the interview process (e.g. contact details) will be securely stored in a password protected database.

Will I be recorded, and how will the recorded media be used?

You will not be recorded during the questionnnaire process.

Should you choose to participate in the interview process, there will be notes taken of your responses, however no audio recording devices will be used.

*Ammendment- due to alterations in the analysis stage of this research, the interview process will now be recorded. Should you consent to be contacted for interviews, an email with an interview participation form will be sent for you to read.

How will my information be managed?

Bournemouth University (BU) is the organisation with overall responsibility for this study and the Data Controller of your personal information, which means that we are responsible for looking after your information and using it appropriately.

Undertaking this research study involves collecting and/or generating information about you. We manage research data strictly in accordance with:

- Ethical requirements; and
- Current data protection laws. These control use of information about identifiable individuals, but do not apply to anonymous research data: "anonymous" means that we have either removed or not collected any pieces of data or links to other data which identify a specific person as the subject or source of a research result.

BU's Research Participant Privacy Notice sets out more information about how we fulfil our responsibilities as a data controller and about your rights as an individual under the data protection legislation. We ask you to read this Notice so that you can fully understand the basis on which we will process your personal information.

Research data will be used only for the purposes of the study or related uses identified in the Privacy Notice or this Information Sheet. To safeguard your rights in relation to your personal information, we will use the minimum personally-identifiable information possible and control access to that data as described below.

Any personally-identifyable information will only be kept for the minumum time necessary to complete this study.

Publication

You will not be able to be identified in any external reports or publications about the research without your specific consent. Otherwise your information will only be included in these materials in an anonymous form, i.e. you will not be identifiable.

Research results may be published, but respondents to the questionnaire and interviews will remain anonymous.

Security and access controls

BU will hold the information we collect about you in hard copy in a secure location and on a BU password protected secure network where held electronically.

Personal information which has not been anonymised will be accessed and used only by appropriate, authorised individuals and when this is necessary for the purposes of the research or another purpose identified in the Privacy Notice. This may include giving access to BU staff or others responsible for monitoring and/or audit of the study, who need to ensure that the research is complying with applicable regulations.

Further use of your information
The information collected about you may be used in an anonymous form to support other research projects in the future and access to it in this form will not be restricted. It will not be possible for you to be identified from this data. To enable this use, anonymised data will be added to BU's online Research Data Repository: this is a central location where data is stored, which is accessible to the public.

Keeping your information if you withdraw from the study

If you withdraw from active participation in the study we will keep information that we have already collected from or about you, if this has on-going relevance or value to the study. As explained above, your legal rights to access, change, delete or move this information are limited as we need to manage your information in specific ways in order for the research to be reliable and accurate. However if you have concerns about how this will affect you personally, you can raise these with the research team when you withdraw from the study.

You can find out more about your rights in relation to your data and how to raise queries or complaints in our Privacy Notice.

As described above, during the course of the study we will anonymise the information we have collected about you as an individual. This means that we will not hold your personal information in identifiable form after we have completed the research activities.

You can find more specific information about retention periods for personal information in our Privacy Notice.

Contact for further information

If you have any questions or would like further information, please contact hbowen@bournemouth.ac.uk

In case of complaints
Any concerns about the study should be directed to the supervisory team led by Tilak Ginige at tginige@bournemouth.ac.uk or to the Deputy Dean, Tiantian Zhang at tzhang@bournemouth.ac.uk
Bournemouth University by email to researchgovernance@bournemouth.ac.uk.

Thank you for considering taking part in this research project.

Appendix 2: Questionnaire to stakeholders

Questionnaire

1. Which of these best describes your profession?

-Agriculture industry
-Public Environmental Sector
-Non-Governmental Organisation
-Academic in the field of law/environment
-Other (please specify)

2. Which part of Great Britain do you currently work in?

-East Midlands
-West midlands
-East Anglia
-Greater London

-Northeast England
-Northwest England
-Yorkshire & the Humber
-Southeast England
-Southwest England
-Wales

3. How familiar are you with the concept of NNIS and their impacts on the British environment?
(Very familiar, fairly familiar, a little familiar, not very familiar, unfamiliar)

4. How familiar are you with current law and policy relating to control of NNIS?
(Very familiar, fairly familiar, a little familiar, not very familiar, unfamiliar)

5. In what ways have you come across NNIS in your line of work?

-Through academic research
-Through NNIS management programme(s)
-Through training course(s) on NNIS/Biosecurity
-Unsure
-Other (please specify)

Section 2: General Non-Native Invasive Species questions

6 a) To what extent do you consider the following factors important in establishing effective NNIS control?
(Score the following between 1 and 10, 1 being not important at all, 10 being extremely important)

-Biosecurity and prevention against further NNIS introduction and spread
-Law and policy focused on preventing and controlling NNIS
-Enforcement to ensure legislation is abided by and offenders are prosecuted
-Scientific research into effective control methods in established NNIS
-Education and public awareness on the threats and best practices of NNIS

b) How effectively have the government applied the following factors in order to prevent and control NNIS spread?
(Score the following between 1 and 10, 1 being not used effectively at all, 10 being used as effectively as possible)

-Biosecurity and prevention against further NNIS introduction and spread
-Law and policy focused on preventing and controlling NNIS
-Enforcement to ensure legislation is abided by and offenders are prosecuted
-Scientific research into effective control methods in established NNIS
-Education and public awareness on the threats and best practices of NNIS

Section 3: Law and policy:

Before beginning this section, the following paragraph gives further information surrounding NNIS law and policy, which you can refer to if required to help in answering the questions in this section:

- *Current British NNIS law comprises of two separate lists. The first is Schedule 9 in section 14 of the Wildlife and Countryside Act. Schedule 9 lists non-native species that are already established in the wild, but which continue to pose a conservation threat to native biodiversity and habitats.*
- *Current policy states that the landowners are responsible for removing NNIS from their land, but only have to act if the species is shown to be dispersing off of their land (Wildlife and Countryside Act, 1981)*
- *Invasive Alien Species (Enforcement and Permitting) Order (2019) addresses species listed on the EU Invasive Alien Species of Union concern. The order also prohibits the ownership of listed species, highlighting 14 priority species requiring management.*
- *Current legislation in Great Britain operates using a blacklisting approach. This approach involves having a blacklist of NNIS that are strictly prohibited in the country (e.g. Schedule 9 and the EU Invasive Alien Species of Union Concern). New Zealand operates a strict whitelist approach. Whitelisting is when a jurisdiction has a whitelist of species that permitted in the country and all species not on the list are strictly prohibited.*

7. To what extent do you agree with the following statements?

(Strongly agree, disagree, neither agree nor disagree, agree, strongly agree)

a) When planning and creating new laws and policies for NNIS control, social, economic and environmental factors are all considered equally

b) When deciding which NNIS are a priority concern, social, economic and environmental factors are all considered equally

8. To what extent do you agree with the following statements?

(Strongly agree, disagree, neither agree nor disagree, agree, strongly agree)

a) Britain should create a consistently funded regulatory body, separate to other bodies, which is specifically focussed on preventing and controlling NNIS.

b) Britain should invest in a biosecurity inspectorate dedicated to NNIS at border control.

c) To encourage proactive responses, the Government should create an initiative for landowners, to fund and assist in the removal of the NNIS on private land, provided they report the species to the appropriate authorities immediately and are cooperative during removal operations.

d) In your view, the necessity to protect native species via culling or other extermination procedures takes precedence over the wellbeing of NNIS.

e) The government should invest more money into campaigns to raise public awareness of NNIS and biosecurity

f) The government should invest more into large-scale eradication projects

9. Which of the following statements do you agree with regarding blacklisting vs whitelisting in preventing NNIS spread?

-Strongly agree with blacklisting
-Agree with blacklisting
-Other (please specify)
-Agree with whitelisting
-Strongly agree with whitelisting

Thank you for completing the questionnaire. Subsequent to receiving the questionnaire responses, we will be conducting semi-structured interview to allow for more comprehensive questioning. This process will give you the opportunity to voice your opinions in a more unrestricted way and give a valuable input into this research. Please select whether or not you are happy to give your consent to be contacted to organise an interview:

-I give my consent to be contacted for interviewing
-I do not give my consent to be contacted for interviewing