Institution: The University of Leeds		
Unit of Assessment: Biological Sciences A05		
Title of case study: Invasive Non Native Species (INNS); improved biosecurity policies, increased awareness and implementation of biosecurity practice amongst environment stakeholder organisations across the Yorkshire Dales and GB, and users of their land.		
Period when the underpinning research was undertaken: 2011-2020		
Details of staff conducting the underpinning research from the submitting unit:		
Name(s):	**Role(s) (e.g. job title):**	**Period(s) employed by submitting HEI:**
Dr Alison M. Dunn	NERC & University Research Fellow Lecturer, S. Lecturer, Reader Professor of Ecology	Sept 1992 - Sept 2000 Oct 2000 - Oct 2020 Oct 2020 - present
Period when the claimed impact occurred: 2015 – present		
Is this case study continued from a case study submitted in 2014? N		

1. Summary of the impact (indicative maximum 100 words)

Invasive Non Native Species (INNS) are a leading driver of biodiversity decline. Furthermore, they threaten ecosystem services including water supplies, impact human health and wellbeing, and increase flood risk. The cost of INNS to the UK economy is ~GBP1,800,000,000 pa. The impact of the work was in raising awareness of INNS and biosecurity in stakeholder organisations across the Yorkshire Dales and nationally; introduction of new, coordinated biosecurity policies for staff and volunteers; implementation of risk assessments and mitigation (biosecurity) for activities with a high risk of INNS spread. These new policies, risk assessments and biosecurity policies and resources have resulted in behavioural change by staff, volunteers and the public with biosecurity now embedded in environmental practice. As a result, risk assessments and biosecurity measures to reduce the risk of INNS spread are now undertaken by staff and volunteers across eight stakeholder organisations working in the environment.

2. Underpinning research (indicative maximum 500 words)

An invasive non-native species is any non-native animal or plant that has the ability to spread causing damage to the environment, the economy, our health and the way we live. The cost of INNS to the UK economy is ~GBP1,800,000,000 pa[#]. INNS are a particular threat in freshwaters; they can drive native species extinct, threaten ecosystem services including water supplies, and increase flood risk. Furthermore, INNS are often linked to the spread of diseases in wildlife and in aquaculture. Once INNS become established, costs of control are large, and total eradication is often unachievable, resulting in spiralling annual costs of treatment. Thus, prevention is the most cost-effective management option available and is key to EU legislation and the GB Non-Native Species Strategy.

INNS can be spread via contamination of clothing, vehicles and equipment used in a range of activities in the environment; accidental movement of just a few animals, plant fragments or seeds can lead to new infestations. **Biosecurity** refers to the practical actions of stakeholders to reduce the risk that their activities accidentally spread INNS. Three strands of research led to this ICS (Summarised in Fig.1, section 4):

i. Improved understanding of the processes of INNS and disease spread, policy gaps and opportunities for prevention. Biosecurity to prevent introduction and spread is key to both infectious disease and invasive species policy. However, we found that international and national legislation and policy to control invasive species lags behind that for diseases (1, 2), that compliance with voluntary practice was low amongst environmental stakeholders with a need for greater cooperation between stakeholders (1, 3, 4).

ii. Understanding UK stakeholder awareness of INNS and attitudes to biosecurity. We evaluated stakeholder awareness and perceptions of their role in INNS biosecurity practice in the UK, in environment researchers (4) and in organisations including business, leisure, conservation, education and public bodies (3). We found variation in awareness of INNS and the capacity of organisations to engage in biosecurity practices (3, 4). We identified key barriers to biosecurity to be costs (including time), lack of clear guidance, difficulties changing attitudes and implementing collective responsibility (3, 4).

iii. Evidence-based INNS biosecurity practice. DEFRA recommends “Check, Clean, Dry” biosecurity treatment for equipment and clothing to kill INNS. However, we identified research

gaps in methods to clean INNS-contaminated equipment. We tested the effectiveness of chemical disinfectant and thermal treatments against key aquatic INNS animals and plants both in controlled lab conditions and in realistic field scenarios (5-8). We showed high effectiveness of hot water immersion in killing INNS (5, 6). In contrast, in collaboration with the Environment Agency, we showed that hot water sprays (widely used to clean boats and other vehicles) were limited in their effectiveness (7). We also demonstrated the effectiveness of chemicals against INNS plants and animals (8). We went on to refine optimum, cost (and time) effective treatments and make recommendations for the range of INNS animal and plant species and for use on contaminated clothing, vehicles and equipment (5-8).
Dunn was PI for the overall research programme (NERC & BBSRC grants) collaborating with Quinn (Sustainability Research Institute, University of Leeds), Roy (NERC Centre for Ecology & Hydrology) and Dick (Queens University of Belfast), the Centre for Environment Fisheries and Aquaculture Research, and the Environment Agency.

[#] https://publications.parliament.uk/pa/cm201919/cmselect/cmenvaud/88/88.pdf

3. References to the research (indicative maximum of six references)
[Web of Science citations as of 06/01/2021]

Improved understanding of the processes of INNS and disease spread, policy gaps and opportunities for prevention

1. Dunn AM & Hatcher MJ. 2015 Parasites and biological invasions: parallels, interactions, and control. *Trends in Parasitology* **31**:189-199 https://doi.org/10.1016/j.pt.2014.12.003 [WOS 87]
2. Roy HE, Hesketh, H…..Dunn, A.M. 2016 Alien Pathogens on the Horizon: Opportunities for Predicting their Threat to Wildlife. *Conservation Letters* **10**:477-484 https://doi.org/10.1111/conl.12297 [WOS 42]

Stakeholder awareness and opportunities and barriers to biosecurity

3. Sutcliffe C, Quinn CH, Shannon C, Glover A, Dunn AM. 2018. Exploring the attitudes to and uptake of biosecurity practices for invasive non-native species: views amongst stakeholder organisations working in UK natural environments. *Biological Invasions* **2**:399-411 http://eprints.whiterose.ac.uk/120440/ [WOS 19]
4. Shannon CF, Quinn CH, Sutcliffe C, Stebbing P, Dally T, Glover A, Dunn AM. 2018 Exploring knowledge, perception of risk and biosecurity practices among researchers in the UK: a quantitative survey. *Biological Invasions* **3**(2):303-314 http://eprints.whiterose.ac.uk/131779/ [WOS 4]

Evidence-based biosecurity practices

5. Anderson LG, Dunn AM, Rosewarne PJ, Stebbing PD. 2015. Invaders in hot water: a simple decontamination method to prevent the accidental spread of aquatic INNS. *Biological Invasions* **17:**2287-2297 http://eprints.whiterose.ac.uk/85906/ [WOS 23]
6. Shannon C, Quinn CH, Stebbing PD, Hassall C, Dunn AM. 2018. The practical application of hot water to reduce the introduction and spread of aquatic invasive alien species. *Management of Biological Invasions* **9**(4):417-423 http://eprints.whiterose.ac.uk/131779/ [WOS 12]
7. Bradbeer S, Renals T…. Dunn AM. 2021+ The effectiveness of hot water pressurized spray in field conditions to slow the spread of invasive alien species. *Management of Biological Invasions* 11. (In press, accepted 02/07/2020)
8. Bradbeer SB,… Dunn AM 2020. The effectiveness of disinfectant and steam exposure treatments to prevent the spread of the highly invasive killer shrimp, *Dikerogammarus villosus. Sci Rep* **10:**1919 https://doi.org/10.1038/s41598-020-58058-8 [WOS 6]

4. Details of the impact (indicative maximum 750 words)

Impact: The impact of our work is in the introduction and implementation of new strategic, coordinated INNS policy across eight key stakeholders for environmental stewardship in Yorkshire **[Sources A-I]**, and in the North **[J]**; increased awareness of the risks of INNS spread; the implementation of INNS risk assessment and mitigation; and behavioural change by staff, environment volunteers and public with biosecurity now embedded in activities that pose a risk of INNS spread. Our research also informed the recent Government Inquiry on Invasive species **[L]**.

How the research led to impact:

Yorkshire area Research led by Leeds University identifying gaps in policy and a need for coordinated approach to biosecurity (1, 2) led us to set up the **Yorkshire Dales INNS Steering**

Group (YD INNS Steering Group; NERC impact accelerator grant GBP25,000, 2015, PI Dunn) comprising partner organisations responsible for Environmental stewardship across the Yorkshire Dales. The mission of the steering group is to coordinate INNS work across the region. Research conducted with these partners identified barriers to biosecurity and stakeholder requirements including the need for cost effective, evidence-based biosecurity guidance, and coordinated biosecurity policy (3, 4). As a result, the Steering Group has produced a coordinated INNS strategy **[A]** for the region (agreed by all partners 2017) and a Red List of INNS of high concern in the region enabling organisations to focus management effort. Leeds University developed and tested evidence-based biosecurity protocols for use by partners (5-8) and we went on to develop risk assessments, evidence-based guidance and protocols tailored for the organisations. AD led a successful bid for a Biosecurity project officer (GBP100,000 NERC Innovation funding matched by partner organisations **[A-I]** 2016). The project officers have worked with each partner organization to deliver the workshops, work-shadowing and/or interviews required to: conduct INNS risk assessment; produce tailored biosecurity protocols based on research evidence from Leeds University (5-8) and develop new biosecurity policy for the partners as detailed below and illustrated in Fig 1.

The work of the YD INNS Steering Group led to invitations to contribute to the Environment Agency Regional Risk Assessment for INNS **[B]**, which informed work with other partners, the steering group of the Yorkshire Invasive Species Forum **[C]** (a Yorkshire-wide INNS group), the Nidderdale Area of Outstanding Natural Beauty Management Plan Steering Group **[D]**, the Yorkshire Dales National Park Management Plan **[E]** and the Yorkshire Water Asset Management Plan 7 Price Review 2019 **[F]**. The YD INNS steering group also contributed to securing funding (EU Rapid Life) for and producing the North Region INNS Management Plan **[J]** (RIMP).

National and wider impact. AD provided written and oral evidence to the UK Parliament Environmental Audit Committee Inquiry on Invasive Species leading to recommendations to include pathogens in future INNS strategy and to increase investment in biosecurity **[L].**

We developed, in collaboration with the Environment Agency and the GB Non Native Species Secretariat, a Biosecurity e-learning MOOC aimed at researchers and informed by our research https://openeducation.blackboard.com/mooc-catalog/courseDetails/view?course_id=_1189_1 (MOOC will be moved to a new host in 2021 owing to changes to blackboard open).

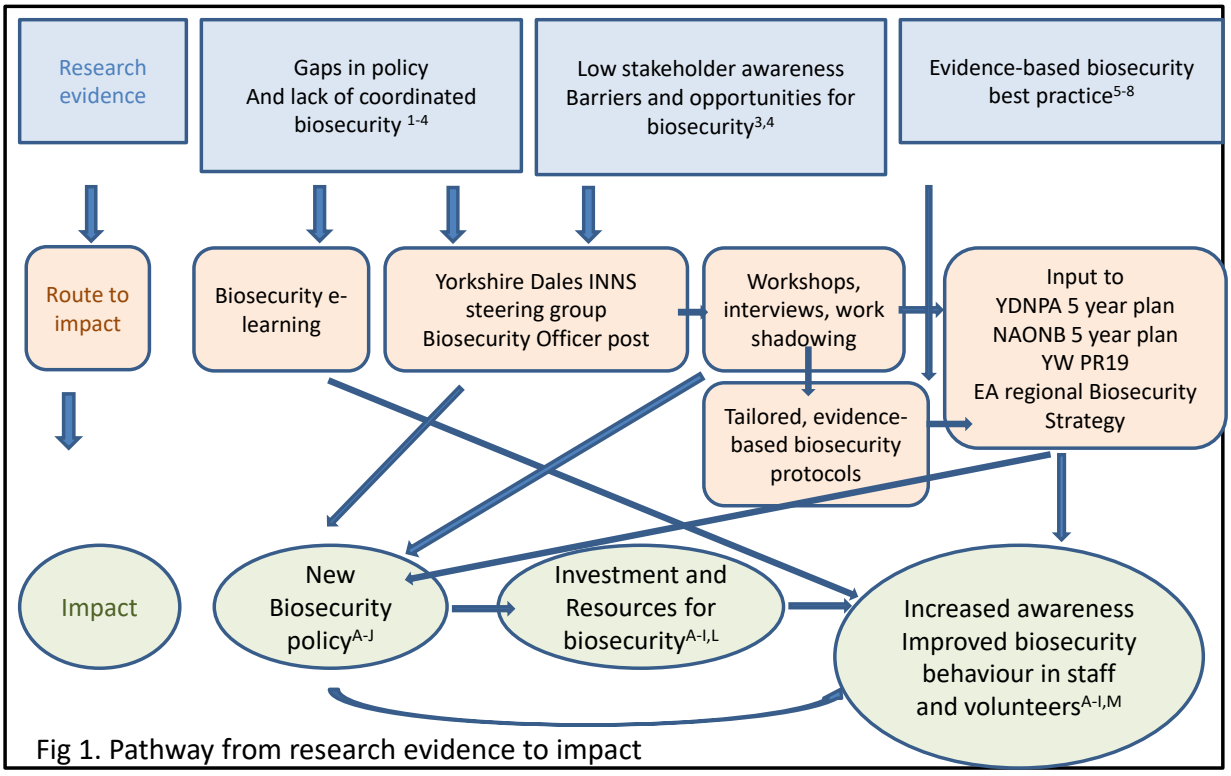

Fig 1. Pathway from research evidence to impact

Details of impact

Since 2015, our Biosecurity MOOC has been taken by >1,000 staff and students from 14 different universities and 124 different environment organisations and companies. A quantitative survey of

participants showed an increase (from 60% to 80% amongst professionals; from 20% to 80% amongst students) in awareness of the risks of INNS and in reported biosecurity behaviour after taking the course. Biosecurity practice also improved; prior to the course 42% of participants reported employing biosecurity measures in the environment, this increased to 81% six months after training [Shannon, C., et al.,. 2020. The effectiveness of e-Learning on biosecurity practice to slow the spread of invasive alien species. Biological Invasions 22:2559–2571 https://doi.org/10.1007/s10530-020-02271-z].

The Environment Agency (EA). We were invited to participate in the advisory committee that developed the Yorkshire Area Biosecurity Risk Assessment and Action Plan which fed into the EA national Biosecurity Action Plan. The plan was used to inform and cost biosecurity facilities at Yorkshire EA Offices and Depots and to inform the Yorkshire Area Biosecurity Protocol that is used by EA staff and contractors across all teams working in the field (Flood Risk Management & Operations, Analysis and Reporting, Biodiversity and Conservation) across Yorkshire (~200 staff) **[B]**. An invitation to speak at the EA national Invasive Species Action Group (ISAG) increased the reach to the national EA which employs 10,000 staff, in flood risk management, regulating waste and water, fisheries, navigation and environmental protection.

Yorkshire Wildlife Trust (YWT). A NERC Engagement grant (GBP25,000 YWT, AD University of Leeds) led to a new biosecurity risk assessment used by ~50 task-day leaders. We also produced evidence-based, tailored training resources and biosecurity guides. As a result, YWT have invested GBP1,250 in biosecurity kits, and now conduct biosecurity training for all 100 staff and 160 volunteers. This has led to biosecurity practices being an integral part of high-risk activities in the 100 Yorkshire nature reserves covering 3000ha **[C]**.

Nidderdale Area of Outstanding Natural Beauty (NAONB). We undertook interviews with key staff and work shadowing to inform INNS risk assessments for key activities, leading to a biosecurity action plan for the organisation and implementation of tailored training for staff and volunteers supported by evidence-based biosecurity guidance. As a result NAONB acquired GBP1,000 Heritage Lottery funding to purchase biosecurity equipment; produced new material on NAONB website https://nidderdaleaonb.org.uk/special-qualities/wildlife-and-habitats/biosecurity/ to raise INNS awareness of businesses, landowners, farmers and public who reside, work in and visit the AONB; and included "*Reducing the impact of INNS"* as an objective in their new Management Plan (2019-2024). The resulting changes in working practice of their 8 staff and ~ 50 volunteers and other land users mitigate for the risk of INNS spread in their 600km^2 of protected working landscape, which includes 9 sites of special scientific interest **[D]**.

Yorkshire Dales National Parks Authority (YDNPA). Interviews with five key teams led to a Risk Assessment for INNS. As a result, ~60 staff now include biosecurity as part of their working practice in the environment. As a result of working with the YD INNS steering group, INNS biosecurity is now included in the management plan (2019-2024) for the 2,000km^2 park (9% of the UK), a quarter of which comprises nationally and internationally important wildlife habitats **[E].**

Yorkshire Water (YW) is the second largest landowner in Yorkshire and has ~3,000 employees. Workshops/interviews led to risk assessments for INNS spread by high-risk staff and the production of evidence-based biosecurity resources tailored for YW. This evidence has been used in the development of the Asset Management Plan 7 (AMP7) programme to ensure that all high-risk staff working in the environment will receive training and appropriate equipment to include biosecurity in their working practices, protecting the 70,000 acres of YW owner land from new INNS infestations. Biosecurity implementation is one of the programmes of work included in the 5 year AMP7 Price Review19 business plan with ~GBP3,500,000 million budget dedicated to INNS (compared to GBP350,000 within PR14 in 2014). YW introduced new biosecurity infrastructure at Thruscross Reservoir (GBP20,000 for a boat and washdown station) to safeguard the Washburn Valley reservoir chain, this will be replicated across other waterbodies where internal staff or third party users are identified as high risk (e.g. sailing/angling clubs) during AMP7 **[F]**.

National Trust (NT). Workshops led to implementation of new INNS risk assessments and of a Biosecurity Action Plan. We advised on risks mitigation for anglers. As a result, anglers (800 bookings pa) visiting Malham Tarn (a protected site of international importance) are now required to undertake a Biosecurity declaration and abide by its requirements **[G]**.

Yorkshire Dales Rivers Trust (YDRT). We ran a workshop to help the YDRT to produce and implement a biosecurity risk assessment and action plan to help embed biosecurity in their operations **[H]** The YDRT is implementing the outputs identified by the action plan, including

biosecurity protocols for staff (8) and volunteers (~30) and biosecurity for events hosted by YDRT, as well as both practical engagement material on INNS and biosecurity for their mobile classroom, which visits local schools (~50 schools visited 2018-19, similar number planned for 2020-21 but disrupted by Covid-19). Our work also contributed to developing and securing funding for the **Dales to Vales Rivers Network** "INNS out" project; this is a catchment wide project that will take forward biosecurity to the DVRN's 60 stakeholders **[H]**

Aire Rivers Trust (ART). We worked with the ART to produce a biosecurity risk assessment and action plan, which the trust used to develop a Biosecurity Policy. We also worked with the Trust to produce online awareness raising material and physical training resources, and advised on the purchase of biosecurity equipment used by their four staff and volunteers (>300 volunteer days pa) **[I].**

Northern Regional Invasive Alien Species Management Plan [J]. RIMPs are intended to bridge the gap between high-level strategies such as the GB Non Native Species Strategy (Defra) and the work done by Local Action Groups. The Yorkshire Dales INNS steering group contributed to successful Defra tender for the Northern Region RIMP (~GBP20,000) and subsequent development of the Management plan for the 11 counties comprising the Northern region.

GB Non Native Species Secretariat. We presented our research findings and shared actions of the Yorkshire Dales INNS steering group at **GB NNSS Local Action Group** conferences (2018, 2019). Evidence from our research on biosecurity practice has been incorporated into training packages of the GN Non Native Species Secretariat **[K]**.

Government Inquiry. AD gave evidence at the House of Commons Environmental Audit Committee in May 2019 where questions on invasive species were posed to a range of academics. This was written up in the Report on the Environmental Audit Committee Invasive Species Inquiry (October 2019) and informed the report's recommendations to include pathogens in future INNS strategy and to increase awareness of and investment in biosecurity **[L].**

5. Sources to corroborate the impact (indicative maximum of 10 references)

A. Yorkshire Dales INNS Strategy http://www.yorkshiredalesriverstrust.com/projects/yorkshire-dales-biosecurity-project/
B. Letter from FBG Advisor to Asset Performance, Environment Agency (dated 04/11/2020)
C. Letter from INNS Project Officer, Yorkshire Wildlife Trust (dated 10/08/2020)
D. Letter from Nidderdale Area of Outstanding Natural Beauty Manager (dated 15/10/2020)
E. Letter from Senior Wildlife Conservation Officer, Yorkshire Dales National Parks Authority (dated 10/11/2020) and https://www.yorkshiredales.org.uk/about/national-park-management-plan/d-climate-change/objective-d7/
F. Letter from Lead Ecologist (Invasive Species), Yorkshire Water (dated 04/08/2020)
G. Anglers' Biosecurity declaration https://www.nationaltrust.org.uk/malham-tarn-estate/features/malham-tarn-fly-fishing
H. Letter from Operations Director, Yorkshire Dales Rivers Trust (dated 08/10/2020)
I. Letter from Chairman of Aire Rivers Trust (dated 09/11/2020)
J. Rapid Life Regional INNS Management Plan, November 2018 http://www.nonnativespecies.org/index.cfm?pageid=632
K. http://www.nonnativespecies.org/elearning/ GB Non Native Species Secretariat Biosecurity module 3
L. Government Inquiry on invasive species, May 2019, https://old.parliament.uk/business/committees/committees-a-z/commons-select/environmental-audit-committee/news-parliament-2017/invasive-species-evidence-17-19/ and first report (Oct 2019) https://publications.parliament.uk/pa/cm201919/cmselect/cmenvaud/88/88.pdf