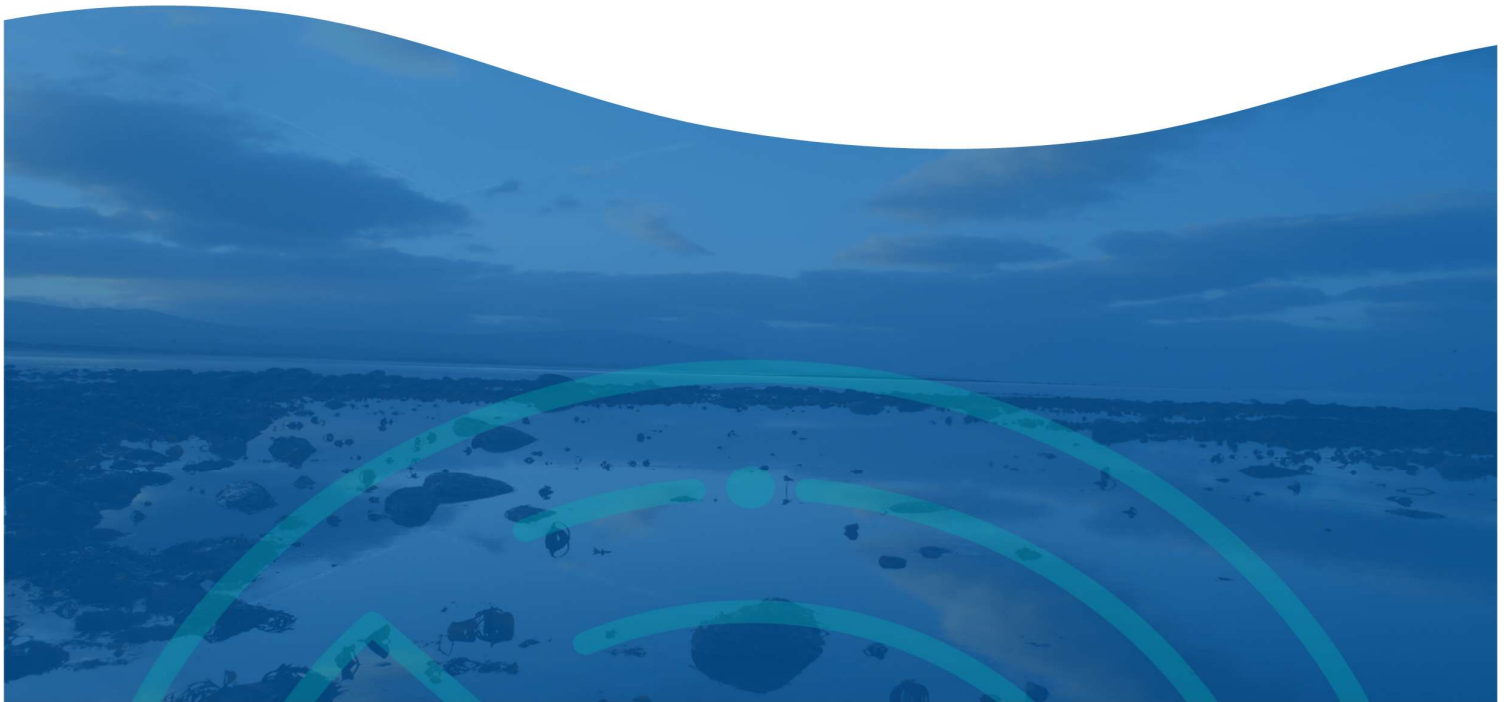


An Invasive Species Surveillance and Monitoring Framework for the Island of Ireland

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Contents

1	Project Background and Aims	1
2	Approach	2
3	Guidance and Frameworks	4
3.1	Site and species prioritisation (Chapter 1).....	4
3.2	Sampling design (Chapter 2)	4
3.3	Data collection and field methods (Chapter 3)	4
4	Data analysis and mapping (Chapter 4)	5
5	Critical Success Factors for the Design of an Invasive Species Monitoring Programme	6
5.1	An improved framework for sampling design	6
5.2	An improved framework for data collection.....	7
5.3	An improved framework for data access and flow	8
5.4	Improved spatial, temporal and priority species coverage through standardised integration of invasive species into existing broader environmental monitoring programmes, with focus on the freshwater and terrestrial environments.....	8
5.5	Enhancement of existing invasive species-specific monitoring programmes in the marine environment	9
5.6	Development and implementation of additional bespoke invasive species monitoring programmes to address shortfalls with respect to priority site-specific legislative requirements	9
5.7	Additional general points to consider	9
6	Implementation Roadmap.....	10
6.1	Governance, roles and responsibilities	12
6.2	Data and information acquisition	14
6.3	Data management.....	15
6.4	Pilot testing and scaling up	15
6.5	Information sharing and engagement	17
6.6	Contingency planning and flexibility	17
6.7	Evaluation and refinement	17
6.8	Cost considerations	18
7	Conclusion and Next Steps	19
8	References.....	20

1 Project Background and Aims

Invasive species¹ are organisms introduced into locations outside their natural range, by human activity, where they cause negative impact². These impacts include predation on, or resource competition with, native fauna and flora; damage to infrastructure; alteration of habitat; and transmission of disease. The impact of invasive species is recognised as a major driver of global biodiversity loss IPBES (2023). In addition, invasive species may have negative impacts on local economies, directly via their effects on recreation and tourism, public utilities, infrastructure, aquaculture and fisheries, and indirectly via management costs. The annual cost of invasive species to the island of Ireland was estimated to be €261,517,445 or £207,553,528 (Kelly et al., 2013).

Surveillance and monitoring for invasive species, is crucial to detect new introductions and inform rapid response; track temporal and geographical changes in their presence and abundance; determine compliance with legislation; and assess progress towards management targets. As such, an effective and efficient surveillance monitoring system for invasive species, covering the terrestrial, freshwater and marine environments of the island of Ireland, is a key component of their effective management.

In 2025, the National Biodiversity Data Centre (NBDC) commissioned this project to support the design of an invasive species monitoring programme spanning the terrestrial, freshwater and marine environments across both Ireland (IE) and Northern Ireland (NI). It comprises two key components: 1) a review of existing surveillance and monitoring focused on, or relevant to, invasive species and 2) recommendations and critical success factors for an invasive species surveillance and monitoring programme that effectively and efficiently generates and captures relevant invasive species data. This report focuses on the second component. The first component is reported in Tidbury et al., (2026a).

The ultimate aim of this report is to provide a series of recommendations, critical success factors and a roadmap to aid implementation of a more comprehensive invasive species monitoring programme. Based on outputs and recommendations from Tidbury et al., (2026a), the focus is on four key components:

1. Improved spatial, temporal and priority species coverage through standardised integration of invasive species into existing broader environmental monitoring programmes, with focus on the freshwater and terrestrial environments.
2. Enhancement of existing invasive species-specific programmes in the marine environment to optimise spatial, temporal and species coverage.

¹ Within this report the term invasive species is used unless specific legislation and associated terms are being referred to. It is intended that the term invasive species covers all related synonyms, such as invasive non-indigenous species, invasive non-native species and invasive alien species.

² For the purpose of this report, the definition of invasive species excludes pathogens and parasites as pathogenic and parasitic invasive species will require very different monitoring approaches (i.e., focused on host infection and health status).

3. Development and implementation of additional bespoke invasive species monitoring programmes to address shortfalls with respect to priority site-specific legislative requirements.
4. Improved data collection, accessibility and flow to support robust reporting.

The following objectives were identified and completed to fulfil the project aim:

- i) Outline methods/framework to prioritise sites for invasive species monitoring
- ii) Identify and collate a comprehensive list of priority invasive species for the island of Ireland
- iii) Evaluate pathways of introduction and spread for priority species
- iv) Analyse how key components of monitoring programme design affect detection outcomes to facilitate optimisation of sampling design.
- v) Provide a manual of monitoring methods, highlighting their relevance to priority species, as well as key considerations for their deployment, including with respect to seasonality.
- vi) Provide key data, maps and notes to facilitate monitoring with improved spatial, temporal and invasive species coverage
- vii) Provide guidance to support data collection and management.

2 Approach

The project provides guidance and frameworks on key components of an effective invasive species surveillance and monitoring programme, site and species prioritisation, sampling design and data collection and field methods, to support strategy, decision making and implementation. Further, through data analysis and mapping, the project provides outputs to enable action in the shorter term, in particular facilitating pilot testing at priority sites. These project components are presented in separate chapter reports and summarised below. Critical success factors are also documented to facilitate the design of a robust and effective surveillance and monitoring programme. Finally, the project outlines key enabling actions and infrastructure, necessary to the successful implementation of more comprehensive invasive species monitoring across the island of Ireland, in the form of an implementation roadmap. This approach is captured in Figure 1.

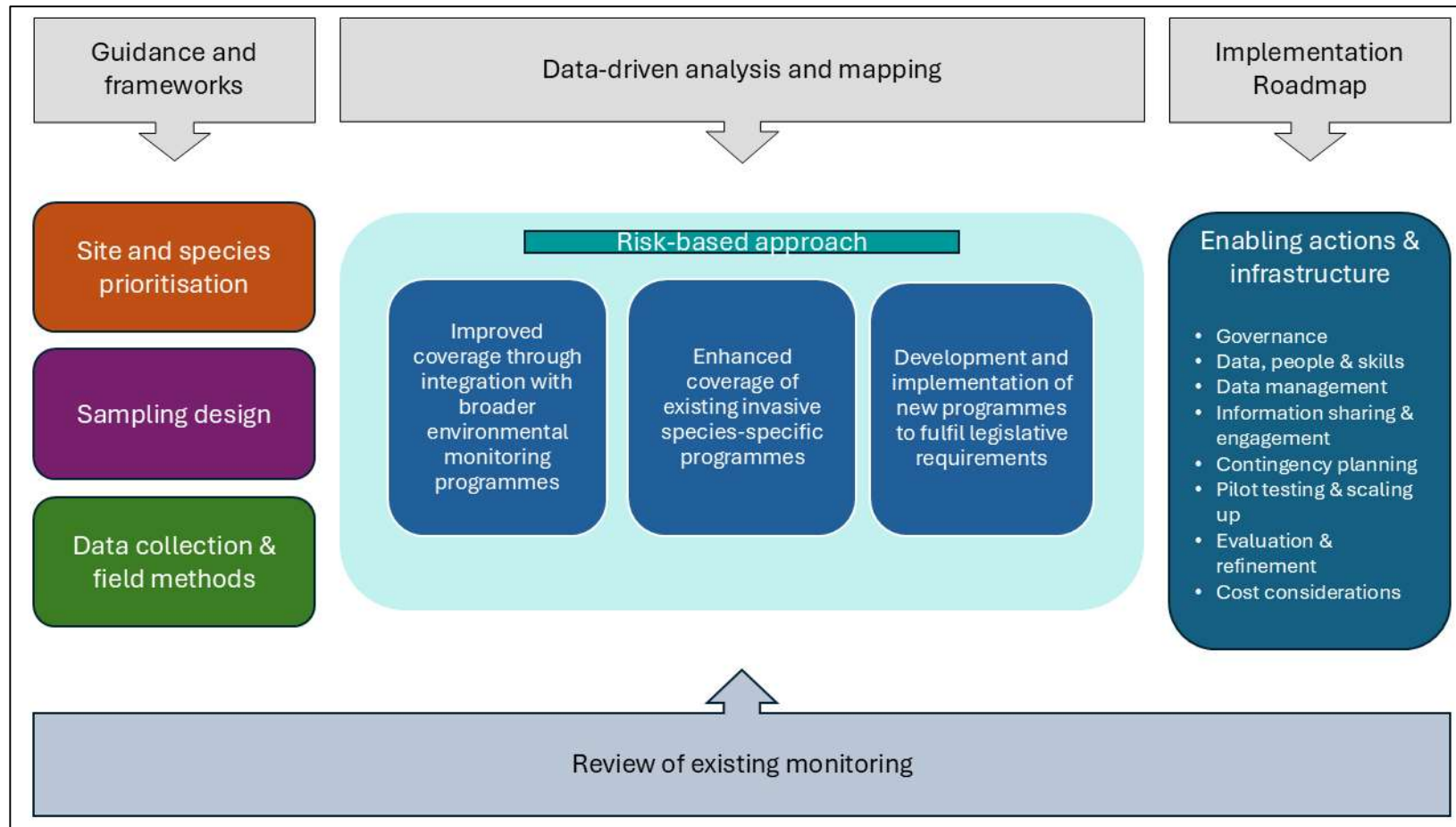


Figure 1. Schematic illustrating the project approach and outputs.

3 Guidance and Frameworks

3.1 Site and species prioritisation (Chapter 1)

Chapter 1 (Tidbury et al., 2026b) supports the prioritisation of sites and species for monitoring. It outlines a framework for prioritising monitoring sites across the island of Ireland based on risk. The framework is structured around four monitoring objectives: baseline surveys, new introductions, rapid response, and spread management. Prioritisation of sites under each objective is driven by specific site metrics, including susceptibility to introduction, establishment, and impact. The framework is modular and adaptable, allowing for different weightings of metrics depending on the monitoring goal and specific objective.

3.1.1 *Priority species*

Within this chapter, a comprehensive list of 187 priority invasive species for monitoring, derived from legislative listings, policy targets, and horizon scanning exercises, is also provided. The list includes Species of Union concern, Ireland's First Schedule Species, Northern Ireland's Schedule 9 species, alert species, and Widely Spread Species. The species are categorised by environment (marine, freshwater, terrestrial) and further classified by traits. The classification system supports method selection (with the aid of Chapter 3) and monitoring design, ensuring that surveillance efforts are aligned with species traits and habitats.

The importance of integrating management feasibility into species prioritisation is also highlighted, based on the GB Non-Native Risk Management Scheme. While there are challenges with conducting accurate risk management assessments due to data limitations, risk management is proposed as a valuable long-term goal for improving the cost-effectiveness of monitoring and response strategies. Note that risk management assessments will be conducted by NBDC within the next five years.

3.2 Sampling design (Chapter 2)

Chapter 2 (Tidbury et al., 2026c) details a theoretical simulation approach to evaluate how different combinations of five key monitoring programme parameters: site risk distribution, sampling approach (i.e., risk-based or random), method sensitivity, number of sites sampled, and sampling frequency, affect monitoring (detection) outcomes.

Furthermore, this chapter details the approach and outputs of a power analysis performed to assess the ability of a monitoring programme (and its resulting detection probability) to detect a statistically significant trend in invasive species introductions over time.

3.3 Data collection and field methods (Chapter 3)

3.3.1 *Data collection, reporting and flow*

Chapter 3 (Tidbury et al., 2026d) outlines key considerations and approaches for standardised invasive species data collection, focusing on presence/absence, abundance, and impact data. It highlights some key considerations with respect to invasive species detections via eDNA and the

need for comprehensive metadata to inform the interpretation of data. It also introduces the concept of monitoring effort analysis to distinguish genuine trends in invasive species introductions/spread from artefacts caused by changes in survey intensity. This chapter also proposes some steps to improve data flow and access, such as annual data submissions to central repositories.

3.3.2 *Field methods*

This chapter also serves as a comprehensive reference guide for selecting and deploying invasive species monitoring techniques across marine, freshwater, and terrestrial environments. It outlines general method considerations such as alignment with monitoring objectives, species traits, seasonal variability, logistical constraints and licensing and certification needs. The document then details a wide array of monitoring methods, including Rapid Assessment Surveys (RAS), settlement panels, scrape sampling, trapping, imaging, environmental DNA (eDNA), walkovers, zooplankton trawls, benthic sampling, fish surveys, ROVs, drones, thermal cameras, tracking tunnels, detection dogs, and bioacoustic monitoring.

Each method is described, highlighting the primary target species and environment it is suited to. The chapter provides a summary table detailing key considerations, including required expertise, costs, logistics, and optimal seasonal deployment. It is intended that this chapter is used primarily with Chapter 1 to cross-reference appropriate methods for each priority species.

The chapter is intended to serve as “live document” that is updated as required, for example, when new methods become available.

4 Data analysis and mapping (Chapter 4)

Chapter 4 (Tidbury et al., 2026e) provides specific data-driven outputs and maps to support the implementation of more comprehensive invasive species monitoring across the island of Ireland. It focuses on three key areas: improved spatial, temporal and priority species coverage through standardised integration of invasive species into existing broader environmental monitoring programmes, with focus on the freshwater and terrestrial environments; enhancement of existing invasive species-specific programmes to optimise spatial, temporal and species coverage; and development and implementation of additional bespoke invasive species monitoring programmes at ports to address current shortfalls identified with respect to the requirements of the Ballast Water Management Convention.

To facilitate the improved spatial, temporal and priority species coverage of invasive species surveillance and monitoring across the island of Ireland, hotspots associated with key pathways linked to priority species were identified and mapped. These hotspot locations focussed on terrestrial and freshwater pathways (given the existing monitoring of marine hotspot locations) and included zoos, wildlife parks, botanical gardens, aquaria, fisheries and finfish aquaculture sites. It is recommended that monitoring is conducted at these hotspots and future work focuses on acquisition of data to underpin risk assessment and prioritisation of these sites. Areas around the island of Ireland (10km² grid cells) which 1) are already monitored 2) have protection designations under relevant legislation and 3) have hotspot locations present were also identified. These areas

are proposed as key candidates for pilot testing more comprehensive monitoring for invasive species through integration with existing broader environmental monitoring programmes.

To facilitate enhancement of existing invasive-species specific monitoring, a risk assessment of marinas and aquaculture sites using number of berths and production area, respectively, as a proxy for invasive species risk, was undertaken. Further, to facilitate the development and implementation of bespoke invasive species monitoring at ports, as required under ballast water management legislation, a risk assessment of ports was conducted using inward tonnage by origin region and number of vessels into port as a proxy for invasive species risk. Recommendations and considerations for invasive species monitoring at these sites are made, and risk in the context of sensitivity to impact is also considered. The analysis conducted on marine hotspot sites provides a case study and outlines a method which can be applied to the freshwater and terrestrial environment.

5 Critical Success Factors for the Design of an Invasive Species Monitoring Programme

Relating to the project components, critical success factors and recommendations are presented below, with the assumption that a programme may be fully developed to spearhead improvements to surveillance and monitoring for invasive species across the island of Ireland, encompassing marine, freshwater and terrestrial environments.

The documentation of critical success factors is intended to facilitate the design of an effective programme structure, accounting for the core surveillance and monitoring programme components (sampling design, data collection and data access and flow), specific approaches proposed to address gaps in existing invasive species surveillance and monitoring, and general recommendations resulting from insight gained through the delivery of the project.

5.1 An improved framework for sampling design

1. The site risk distribution, sampling approach (i.e., risk-based or random), method sensitivity, number of sites sampled, and sampling frequency affect monitoring (detection) outcomes, with monitoring robustness (reduced time to detection and increased probability of detection) optimised when:
 - a. The number of (unique) sites surveyed is high,
 - b. The monitoring method sensitivity is high (if sensitivity cannot be improved, increasing the number of sites can help compensate),
 - c. The sampling approach accounts for the site risk distribution.

Detection of statistically significant trends in invasive species introduction requires that the monitoring programme has high detection probability. More specifically, the detection of a significant trend to the power of 80 or 95% requires that the monitoring programme's detection probability is ≥ 0.55 or > 0.9 , respectively. Monitoring programme designs therefore need to maximise detection probability - for example, through increased method sensitivity,

and strategic sampling based on site risk distribution - to reliably detect and respond to invasive species trends.

5.2 An improved framework for data collection

1. A huge variety of methods are available for invasive species monitoring, ranging from more traditional visual techniques (e.g., Rapid Assessment Survey (RAS), walkovers) to those applying novel technologies (e.g., eDNA, drones).
2. No single monitoring method is effective for detecting all priority invasive species, or applicable across all environments/sites. A toolbox approach, using multiple complementary methods, is often the most effective strategy.
3. The monitoring objective and goal should be considered when selecting an appropriate method, for example:
 - a. New introductions/ early detection – methods which determine presence/absence only, may be suitable.
 - b. Tracking establishment and spread – methods which determine abundance and establishment status (including detection of early life stages and assessment of reproductive status of adults), as well as presence/absence are required.
 - c. Assessing ecological impacts – methods which consider presence, establishment status and abundance in the context of the broader ecosystem are required.

Triggers for management action should be considered under each objective.

4. Methods should be selected to account for species' characteristics and ecological traits. In particular, consideration should be given to when the species is likely to be most conspicuous or abundant. For detection of early life stages, traits such as spawning season will need to be considered.
5. Logistical and operational aspects, such as availability of expertise, capacity for sample handling, storage and analysis, accessibility of sites, and safety of personnel, also require consideration (see implementation roadmap below).
6. Necessary permissions (access to private land) and licenses (e.g., crayfish trapping, drone surveys) will need to be sought prior to undertaking monitoring.
7. Data collection should be standardised across programmes to collect presence/absence, abundance, and impact data.
8. Absence data should be recorded where possible, i.e., when survey effort is sufficient to detect the species if present. Confidence scores, recorded against absence records could further support the reporting of absences.
9. Comprehensive metadata, including survey details, methodology, environmental conditions, and quality assurance indicators should also be recorded.
10. Standardised templates, supported by end point data repository requirements should be developed and used to support consistency and streamlined data submission and sharing.

5.3 An improved framework for data access and flow

1. Invasive species records should be evaluated in the context of monitoring effort to allow actual trends in invasive species introduction/spread to be delineated from artefacts resulting from changes in monitoring effort.
2. All invasive species records should be submitted to centralised repositories (e.g., National Biodiversity Data Centre, CEDaR) annually, with a specific timeframe or deadline in place, where appropriate.
3. Memorandums of Understanding (MoUs) and legal mechanisms to support regular data submission should be explored.
4. Automated linkages between national databases and central repositories should be established, where possible.
5. Options to overcome issues around data sensitivities should be explored.

5.4 Improved spatial, temporal and priority species coverage through standardised integration of invasive species into existing broader environmental monitoring programmes, with focus on the freshwater and terrestrial environments.

1. It is recommended that surveillance and monitoring is conducted at hotspot locations identified (zoos, wildlife parks, botanical gardens, aquaria, fisheries and finfish aquaculture sites).
2. Pilot testing of more comprehensive invasive species monitoring through integration into existing broader environmental monitoring programmes (e.g., driven by the Water Framework Directive (2000/60/EC) and Habitats Directive (92/43/EEC), and associated national implementation legislation) should be prioritised where hotspot sites occur and sensitivity to impact is high.
3. Higher resolution evaluation of priority locations for integrated monitoring should include assessment of types of protected sites and their relevance to the hotspot sites (i.e., the associated pathway and the priority species of relevance).
4. Future work should focus on acquisition of data on pathway activity to underpin risk assessment and prioritisation of hotspot sites, following the approach outlined for the marine environment (sections 5.5 and 5.6).
5. In addition to integrating invasive species monitoring into existing environmental programmes, bespoke monitoring at hotspot locations in the terrestrial and freshwater environments will likely be required to ensure adherence to invasive species legislation, namely the Invasive Alien Species Regulations (1143/2014) and its relevant implementing legislation (see Legislation Summary in Supplementary Material).

5.5 Enhancement of existing invasive species-specific monitoring programmes in the marine environment

1. Surveys carried out under existing invasive species-specific monitoring programmes (i.e., at marinas and marine aquaculture production sites (Tidbury et al., 2026a)) in particular at the highest risk sites identified, should be increased to annual or biennial frequency.
2. Methods currently deployed at hotspot sites should be supplemented to improve detection of priority species. For example, the deployment of baited traps during marina surveys will enable the detection of mobile pelagic and benthic species.
3. Pathway activity data such as recreational boating pathway activity levels and aquaculture import / stock movement frequency, should be incorporated where possible, into future site risk assessments.

5.6 Development and implementation of additional bespoke invasive species monitoring programmes to address shortfalls with respect to priority site-specific legislative requirements.

A key gap identified during the analysis set out in Tidbury et al., (2026a) is that there is no current monitoring for invasive and non-indigenous species in commercial ports. The development and implementation of additional bespoke monitoring to address this gap, and adhere to ballast water management legislation is now urgently required. The following is recommended:

1. Implement monitoring at ports. To start, all ports should be surveyed to provide baseline data. Subsequently, the highest risk sites should be identified through robust data analysis, and selected for most frequent monitoring (annual or biennial).
2. Select monitoring methods appropriate for species with pelagic life stages (including larvae and juveniles), as well as fragmenting or fouling species including zooplankton trawls, settlement panels; RAS; baited traps; and eDNA (see Chapter 3 for detailed information on invasive species monitoring methods, including seasonal considerations).

Future port risk evaluation should include use of vessel tracking data (e.g., AIS data) to better understand traffic into and between ports located across the island of Ireland, and identification of high-risk origin ports, in terms of priority invasive species presence and climatic matching.

5.7 Additional general points to consider

1. A number of projects are currently underway to improve invasive species monitoring at various national, regional and local scales (e.g., GuardIAS). Project outputs (when available) should be reviewed and used to inform surveillance and monitoring for invasive species across the island of Ireland.
2. The large number of organisations and stakeholders across IE and NI highlights the need for strong coordination and communication. Transboundary cooperation and communication are also key for pre-border risk assessment.
3. Building on existing programmes, communication networks and protocols provides a great opportunity to improve cost-effectiveness but should not be seen as a low effort, easy fix. It

is important to be ambitious and strive for the best invasive species monitoring in terms of spatial, temporal and species coverage possible.

4. The 'take once, use many' concept of integrated monitoring should be considered at all times. Sharing the practical and economic burden of environmental monitoring across multiple sectors is an advantage. However, to achieve this, strong communication between relevant sectors is needed, with focus on engagement at the planning stages to ensure multiple objectives can be incorporated effectively into the proposed programme.
5. Pathway activity data is crucial to inform site prioritisation yet is very limited, with inconsistencies across IE and NI. This is particularly true for freshwater and terrestrial pathways. Opportunities to generate data to inform pathway activity assessment and site prioritisation should be explored, for example, via studentships and research collaborations.

6 Implementation Roadmap

Key enabling actions and infrastructure, necessary to the successful implementation of more comprehensive invasive species monitoring across the island of Ireland and delivery of the critical success factors outlined in Section 5 above, are:

- i. governance,
- ii. roles and responsibilities,
- iii. data and information acquisition,
- iv. data management,
- v. pilot testing and scaling up,
- vi. information sharing and engagement,
- vii. contingency planning and flexibility,
- viii. evaluation and refinement,
- ix. cost considerations.

These are summarised in Figure 2 and covered in more detail below, providing a roadmap to guide implementation.

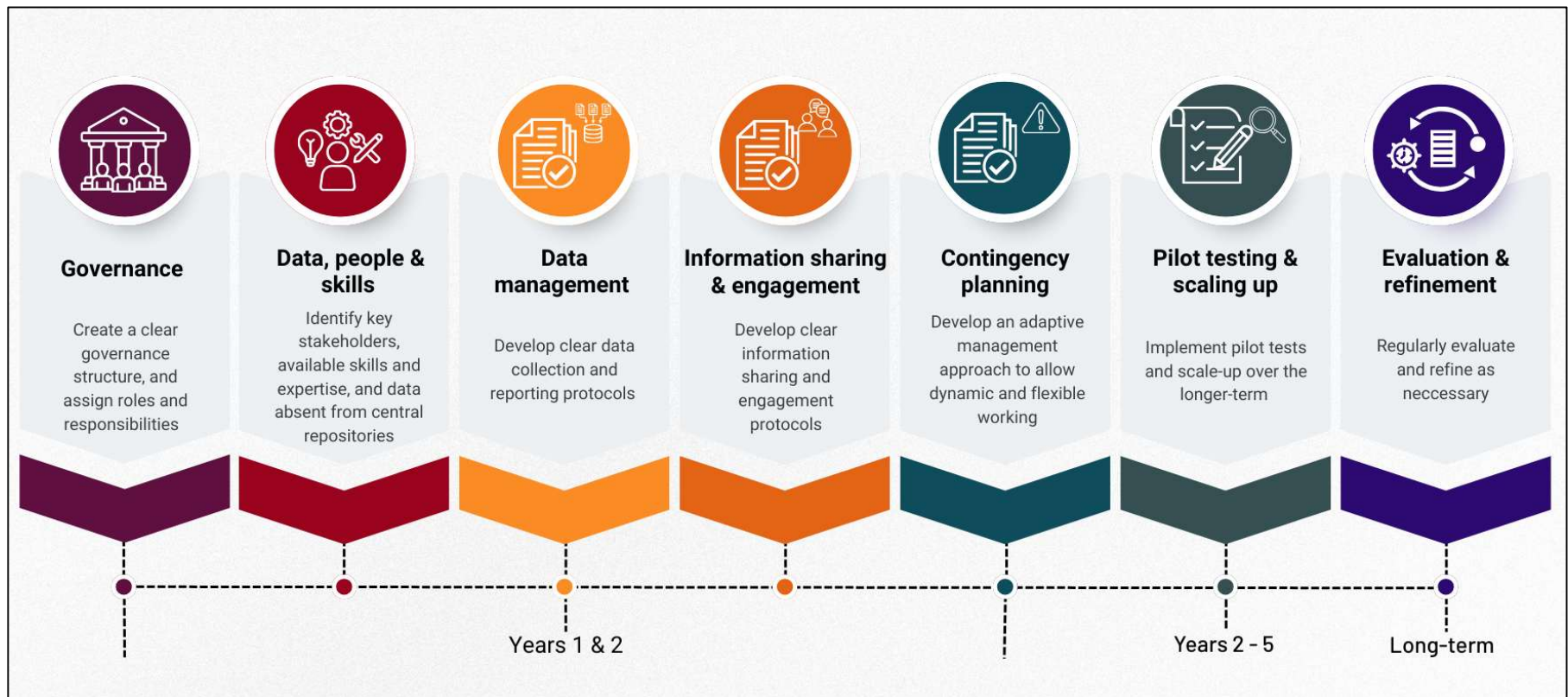


Figure 2. Roadmap illustrating key steps for progression towards a more comprehensive invasive species surveillance and monitoring programme across the island of Ireland.

6.1 Governance, roles and responsibilities

A clear governance structure, and assignment of roles and responsibilities with respect to invasive species monitoring across the island of Ireland, is essential. It ensures transparency and accountability, while also facilitating the acquisition of relevant support for the fulfilment of assigned roles. This is especially important as this programme encompasses multiple organisations and sectors across all environments and two jurisdictions.

Suggested core roles and associated responsibilities are outlined in Table 1. The responsible authorities (i.e., the Policy Lead) has overall accountability and has the authority to empower the Lead Authority to act. The Lead Authority (i.e., the Programme Coordinator) is responsible for the day-to-day delivery of the programme. It is acknowledged that the roles highlighted may already exist in some form. However, it is recommended that existing governance, roles and responsibilities are reviewed in light of the fact that responsibilities are likely to increase in scale, and shift in scope, with the implementation of more comprehensive monitoring for invasive species.

Table 1. Suggested core roles and governance structure to support the long term implementation of coordinated and comprehensive monitoring for invasive species across the island of Ireland.

Title	Role	Responsibilities	Notes
Policy Lead(s)	Acting Responsible Authority role. Provide high-level, policy aligned direction and strategy. Empower Lead Authority to act and ensure the availability of funding.	Set policy aligned strategic monitoring priorities and targets. Advocate for the programme and secure funding as required for agreed implementation. Oversee implementation, and its evaluation and adaptation. Oversee relevant reporting. Sign off on the assignment of staff to rapid response monitoring.	It is likely that this role will need to be duplicated in NI and IE but its remit should be identical. This role will be best suited to government agencies such as NPWS and DAERA.
Programme Coordinator	Acting Lead Authority role which drives action and provides day to day coordination of the programme.	Liaise with Policy Lead and delivery teams, e.g., including through chairing of thematic expert groups. Oversee the development and maintenance of monitoring protocols, to provide standardisation. Coordinate data collection, analysis, and reporting according to the guidance outlined in Chapter 3, including data validation. Lead monitoring programme evaluation and adaptation. Manage contracts and partnerships. Engage with stakeholders and citizen scientists. Coordinate rapid response monitoring and ensure that a protocol is in place for assignment of staff to rapid response under contingency planning†.	A role (or roles) which spans both jurisdictions will allow greatest level of coordination. This role is likely to be beyond the capacity of a single individual. For multiple individuals sharing this role, clear delineation will be needed to ensure that effort is not duplicated and all elements are covered.
Thematic Expert Group(s)	Provide technical expertise.	Led by the Programme Coordinator, provide scientific evidence and advice to support delivery, evaluation and adaptation, including changes to regional and thematic priorities. Assist the delivery teams with protocol development (i.e., provide expert review).	The organisation and specific terms of these groups may require some consideration and dynamism. Themes (and associated terms) could reflect geographical regions, environment, primary method, primary target species. Existing groups should be reviewed and where possible their remit extended, rather a new group created.
Delivery Team(s)	Coordinate monitoring on the ground. Implement monitoring and data collection/recording.	Conduct surveys, sample collection, lab analysis etc. Submit data to appropriate repository according to the guidance developed in Chapter 3— a data manager could be	Consideration should be given to all delivery elements including, field, lab, image analysis and data analysis teams, as appropriate for the methods deployed.

Provide data analysis /GIS specialist support.	assigned within the delivery team to oversee this. Report training and capacity building needs to the programme coordinator. Ensure all training, HSEQ etc requirements are up to date – a training coordinator could be assigned within the delivery team to oversee this. Support rapid response and biosecurity actions.	Delineation of delivery teams, and designation of a lead, by theme (similar to those used for expert groups) should be considered to help with streamlining of communications etc.
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†invasive species contingency plans include monitoring but are more focussed on management action. However, rapid response monitoring responsibilities will need to align across general monitoring and contingency plan governance structures.

6.2 Data and information acquisition

Collation of information and data will be crucial to the planning and implementation of an improved invasive species monitoring programme. In particular, an up-to-date stakeholder list, collation of invasive species records currently not available on centralised repositories, and information on currently available skills and resources:

6.2.1 Stakeholder Identification

A list of stakeholders involved in invasive species monitoring, and/or environmental monitoring more broadly, across the island of Ireland should be collated. This list should include relevant organisations, job roles and contact details. Where possible, this should include general department/topic area emails -this will ensure the longevity of contact details independent of any staffing changes. This list should be comprehensive and include details of personnel or organisations involved in sample analysis in the laboratory (i.e., taxonomists, image analysts, molecular ecologists). This list will help when designating field and analysis teams under steps 6.4.4 and 6.4.5. This list should be stored centrally and reviewed and revised frequently or when significant changes occur (e.g., following new recruitments, organisation restructure).

6.2.2 Invasive species records

A recent review of existing invasive species data has highlighted that essential data may not be reaching key national centralised repositories (i.e., CEDaR and NBDC). It is crucial that steps are taken to enter all existing invasive species records onto central repositories, as these records may affect the selection of priority sites for pilot testing and future scaling up.

When all available data are collated, records for the priority species should be analysed and used to guide monitoring site selection. For example, geographical gaps should be targeted for baseline surveys (see Chapter 1 – Site prioritisation and Section 6.4.2 below). Subsequent to this initial collation of existing data, guidance on submitting records proposed under Chapter 3 should be followed.

6.2.3 Skills, equipment and resource audit

A thorough skills, equipment and resources audit across all sectors and organisations involved in invasive species monitoring and broader environmental monitoring is required to understand current status and capacity. There are a number of approaches that could be used. One suggestion is the creation of an online questionnaire to be completed by all identified stakeholders (see section 6.2.1). Questions should be closed, with explicit options where possible, to streamline responses and speed up the assessment process. Data should be stored centrally and reviewed and revised frequently or when significant changes occur (e.g., new technical areas are created).

These data should be used under section 6.4.6 below to identify where existing skills and resources can be utilised, and where training and/or recruitment is necessary.

6.3 Data management

A robust and transparent data management protocol is required to ensure that data collected currently, and via the improved invasive species monitoring programme, are entered onto central repositories (i.e., CEDaR and NBDC). This is essential to enable all invasive species records to be used in informing management actions and future monitoring programme refinements as well as underpinning reporting requirements. In the absence of legislation to obligate submission of data to appropriate repositories, this protocol requires engagement with key stakeholders and could include the establishment of MoUs to formalise data sharing agreements. This protocol needs to include an explicit reference to the speed with which records must be submitted (i.e., the maximum time between data collection and submission to a central repository) and the specific data required. Potential data sharing sensitivities (e.g., invasive species records on private land) need to be understood, and possible solutions drawn up and agreed upon to mitigate these. For example, options could include lowering the resolution of invasive species record geo-spatial reference or fixed closed data time period, beyond which records need to be shared (also see Chapter 3 for guidance on data collection and management).

As outlined above under 4.1, data could be submitted to central repositories via the programme coordinator.

6.4 Pilot testing and scaling up

A comprehensive monitoring programme for invasive species across the island of Ireland will take some time to implement fully. It is suggested that pilot tests and trials are conducted, and lessons learnt exercises are undertaken, prior to scaling up. A number of steps are outlined below to facilitate the planning and implementation of each pilot test and its scaling up. It is anticipated that these steps will be actioned, or at least coordinated, by the Programme Coordinator.

6.4.1 Objective

The objective of the pilot study needs to be clearly defined and communicated to all involved. This may include reference to monitoring purpose (i.e., detection of new introductions), the focus environment, specific pathways (and associated site types), or priority species of focus.

6.4.2 *Selection of Sites**

Sites for pilot testing should be selected. Selection will depend on the objective of the pilot test. For this step, Chapters 1 and 4 should be referred to, to facilitate a new site prioritisation exercise, or to guide selection of sites based on their pathway activity, sensitivity etc, respectively. Site selection may also consider logistics and ease of access, especially where the objective of the pilot test is to trial a method or its deployment by a particular team – adding site complexities may impede such a trial and potentially increase time and costs.

Permissions will need to be sought from landowners as necessary and should be factored into the pilot test timeline to ensure permission issues do not impact pilot testing start times.

6.4.3 *Selection of Methods**

Appropriate methods should be selected, taking into account the defined objective. For this step of the road map, Chapters 1 and 3 should be referred to, and used to select the appropriate method(s) to achieve the objective.

6.4.4 *Designation of survey teams**

A field team should be designated for the pilot test. This may be within a single organisation but could span multiple organisations. The existing commitments of the team as well as their skills and expertise, should be considered as part of the selection process. The team size will depend on the site and methods selected and should account for lone working risks.

*Note that the order of consideration of these steps may need to be altered. For example, it may be that a specific survey team is selected to run a pilot, and the methods and sites are chosen with the designated team in mind (i.e., their geographic location, skills, equipment, and existing environmental monitoring schedule).

6.4.5 *Designation of sample and data analysis teams*

It is essential to consider what additional personnel/ organisations are needed in order to complete sample analysis and data processing. In particular, for several methods, samples are taken for subsequent laboratory analysis (e.g., eDNA samples require DNA extraction, PCR, and sequencing; physical samples require taxonomic identification, and images require analysis). Prior to the deployment of the pilot tests, these roles need to be assigned and communicated. As part of this step, consideration should also be given to sample storage and transport, as required.

6.4.6 *Equipment and Training needs*

The equipment and skills required for the pilot test should be identified, primarily based on the selected monitoring method (see Chapter 2). The requirements for the pilot test should be cross-referenced against the existing skills and equipment held by the designated team (i.e., using information acquired under 6.2.3). Any gaps identified will need to be addressed through procurement and training. Training for the use of purchased equipment, including any necessary certification, will need to be accounted for in the pilot test timeline.

6.4.7 *Sample collection and analysis protocols*

Standardised and robust protocols, for field sample collection, sample storage and analysis, are required for pilot testing and scaling up. Protocols should include reference to sampling design, including the number of sites and the frequency of sampling which can be informed by simulation outputs detailed in Chapter 2. Data collection should also be explicitly included in protocols, for example whether presence and absence data only are required, or whether abundance data are required and which scale should be used for abundance scoring (e.g., SACFOR) (see Chapter 3). Protocols should follow existing and established field protocols where relevant. Any protocols prepared should be reviewed by an expert group and shared widely by the Programme Coordinator to ensure consistency (as outlined under section 6.1). The protocols should reference/link to the data management protocol as per section 6.3.

6.5 **Information sharing and engagement**

Coordination and harmonisation across the island of Ireland requires frequent and effective communication. As outlined in section 6.1, clear roles and responsibilities with respect to information sharing and engagement are required. Further, as outlined in section 6.2, access to up-to-date and robust data and information is crucial. Existing invasive species related communication channels, platforms and forums should be evaluated, and the potential for their scope to be broadened to include information sharing with respect to monitoring specifically, considered. While there is often temptation to create new communication channels and platforms, it is recommended that existing ones are utilised where possible and improved upon where necessary.

6.6 **Contingency planning and flexibility**

Contingency planning will be required for pilot testing and scaling up of the monitoring programme. Contingency plans should outline the necessary actions to be taken in response to specific scenarios. For example, contingency plans could be developed for a scenario under which a priority species is detected, and planned routine monitoring is halted, with resources redirected to target the introduced species. Contingency scenarios should be discussed with the expert group and plans should be reviewed and signed off by them.

Note that contingency planning elements should also be included in the sample collection and analysis protocols to cover survey-specific scenarios (i.e., related to extreme weather) and necessary actions for mitigation.

6.7 **Evaluation and refinement**

Regular and frequent review and evaluation of the monitoring programme, including pilot testing, should be undertaken. A template should be created for this process. The following sections are proposed for inclusion: i) programme or pilot test overview, ii) a review of whether the defined objectives were met, iii) an evaluation of the methods deployed including any limitations or issues, iv) assessment of adherence to data management expectations, v) resource use and cost efficacy, vi) feedback from field and sample analysis teams, and vii) recommended actions to improve and enhance the programme. The process should be formally documented each time it is undertaken.

The application of new and emerging technologies to support the implementation and refinement of an invasive species surveillance and monitoring programme, and improve its accuracy and cost-effectiveness, should be considered at the development and evaluation stage.

6.8 Cost considerations

There are a number of costs associated with an invasive species monitoring programme that will require consideration. Some of the key costs are summarised in Table 2

Table 2. Summary of potential costs associated with a comprehensive and coordinated monitoring programme.

Category	Item	Cost Type	Description / Examples
Personnel	Project coordination and management	Programme cost	Principal investigator, coordination, reporting, stakeholder liaison. This role may require multiple personnel.
	Data analyst / manager	Programme cost	To provide GIS, data entry, analysis etc as required.
	Technology specialist	Programme cost	Aimed at helping to adopt new / emerging technologies efficiently and effectively (e.g., AI, drones, eDNA, etc).
	Delivery teams	Programme cost	Staff time/cost, accounting for the size of the delivery team and their salary.
	Training	Programme cost	Internal and external training – to include workshops, materials, course fees, certification etc.
Contractor support	Contractor	Programme cost	Specific surveillance and monitoring programmes are likely to require contractor support. What support will be required will depend on the lead organisations core capacity.
Equipment and Consumables	Monitoring tools	Programme cost	E.g., Traps, nets, sample containers, boats, eDNA kits, camera traps, thermal binoculars, drones- according to method, environment and species - including servicing costs.
	Digital devices	Programme cost	Phones, tablets, GPS trackers, cameras –including servicing costs.
	PPE	Programme cost	As required for health and safety compliance.
	Consumables	Programme cost	Field and lab consumables.
Travel and Logistics	Transport	Programme cost	Vehicle hire, fuel, mileage.
	Accommodation	Programme cost	Overnight stays when needed.
	Subsistence	Programme cost	Meals when needed.
Data Management	Software licenses	Core function	GIS, data, analysis software (open source software should be considered where possible).
	Database maintenance	Core function	Server costs, technical support.
	Data validation	Core function	QA/QC processes – expert fees.
Lab Analysis	Sample processing	Programme cost	eDNA, image analysis, other lab analysis.
	Sample shipping	Programme cost	Courier or postal costs.
	Sample storage	Programme cost	Samples may require specialist storage including freezing.
Awareness and Stakeholder Engagement	Workshops / meetings	Programme cost	Venue hire, facilitation, organisation.
	Outreach materials and platforms	Core function	Reports, summaries, SharePoint, ArcGIS story maps and Dashboards etc.

Category	Item	Cost Type	Description / Examples
Contingency	Equipment replacement	Programme cost	Replacement of lost equipment, repair of damaged equipment.
	Weather delays	Programme cost	Additional travel/ survey time required for delivery teams.
	Incursion event	Programme cost and Core function	An incursion of a high impact species may require deprioritising some work and redeployment of the team to a specific geographic area for delimiting surveys.
Information and data sharing	Communications materials	Programme cost	Infographics, information materials, website maintenance, or other project collateral to help raise awareness and support more effective data sharing.
Reporting and Evaluation	Report writing	Programme cost	Staff time and any printing costs.
	Publication	Programme cost	External review / audit, publication fees.
Management	Overheads	TBC	Office, insurances, pensions and other costs should be considered.
Other	Inflation risks	TBC	Inflation costs are difficult to predict and therefore a strategy is required to manage these risks.

7 Conclusion and Next Steps

A well designed and resourced programme, underpinned by the project outputs, has the potential to drive substantial efficiencies in the surveillance and monitoring for invasive species across the island of Ireland. Such a programme will also ensure that both jurisdictions are delivering towards legislative objectives and recommendations set out above and in related reports (e.g., Mirimin et al., 2019).

In order to create a strong foundation and improve the longevity of the developed programme, priority should be given to addressing the requirements laid out in the road map. Key next steps include:

1. Identification of Responsible Authorities and lead roles (including initiation of recruitment to fill required roles where necessary) with emphasis on cross jurisdictional coordination.
2. Creation of a list of relevant stakeholders (colleagues whose role relates to coordination/implementation of invasive species monitoring or broader environmental monitoring). This will help with point 1.
3. Upload of invasive species occurrence records held locally to central repository.
4. Drafting of specific data collection protocols, data sharing strategies and detailed field method protocols; incorporating these into existing protocols where possible.
5. Drafting of information sharing and communication strategies, identifying any specific infrastructure that is required.
6. Evaluation of available resources and drafting of pilot testing approach (detailing the objective, site, species, methods, field teams) within budget identified.
7. Identification, and where possible implementation, of mechanisms (i.e., citizen science initiatives, research projects) to generate crucial data to inform pathway activity assessment and site prioritisation, especially in the terrestrial and freshwater environments.

8 References

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