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Invasive Non-native Species Pathway Action Plan:

Aquaculture in Wales

May 2026

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APEM Ltd. and Natural Resources Wales

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    - dyframaeth pysgod cregyn rhynglanwol sy'n defnyddio trestlau neu bolion
    - dyframaeth pysgod cregyn rhynglanwol a gesglir o wely'r môr
    - magu pysgod cregyn mewn deorfeydd;
    - dyframaeth rhynglanwol plannu gwymon;
    - dyframaethu gwymon islanwol gan ddefnyddio rhaffau a/neu rafftiau;

    - dyframaethu pysgod cregyn islanwol gan ddefnyddio rhaffau a/neu rafftiau; a
    - dyframaeth pysgod cregyn islanwol a gesglir o wely'r môr.
- Mae'r Cynllun Gweithredu Llwybr yn amlinellu saith cydran o ffocws bioddiogelwch ar gyfer y llwybr dyframaethu o fewn ardaloedd morol Cymru:

    1. Deall rolau a chyfrifoldebau cyfreithiol.
    2. Hyrwyddo gwybodaeth ac arweiniad ar rywogaethau estron goresgynnol a bioddiogelwch.
    3. Codi ymwybyddiaeth
    4. Prosesau a gweithdrefnau bioddiogelwch
    5. Cyfleusterau bioddiogelwch.
    6. Gwyliadwriaeth ac adrodd
    7. Gweithio ar y cyd

- Darperir enghreifftiau o gamau ymarferol (rheoli) ar gyfer gweithredwyr dyframaethu, ynghyd ag enghraifft o brotocol ar gyfer symudiadau hadau cregyn gleision ac ystyriaethau ar gyfer cynnal a chadw safleoedd a gweithrediadau adeiladu.
- Bwriedir i'r cynllun hwn gael ei ddefnyddio i gefnogi'r Cynlluniau Gweithredu Rhywogaethau (SAPS), a Chynlluniau Gweithredu Bioddiogelwch (BAPS) cysylltiedig.

Mae'r Cynllun Gweithredu Llwybr hwn yn cydnabod bod awdurdodi fel Busnes Cynhyrchu Dyframaethol (APB) yn cynnwys cwblhau Cynllun Mesurau Bioddiogelwch ar gyfer atal/lleihau clefydau. Er y bydd gorgyffwrdd yn anochel, nid yw'r Cynllun Gweithredu Llwybr hwn wedi'i fwriadu i ddiystyru unrhyw un o'r gofynion na'r canllawiau cysylltiedig a ddarperir o dan Reoliadau Iechyd Anifeiliaid Dyfrol (Cymru a Lloegr) 2009.

Executive Summary

- Invasive non-native species (INNS) are plants, animals or pathogens that do not naturally occur in an area but have been moved there, by human activities (either accidentally or deliberately) and cause significant environmental, social or economic impacts. The impacts of INNS include outcompeting native species for food and space, altering habitats, spreading disease and incurring direct and indirect costs for local and national economies.
- The movement (i.e. the introduction and spread) of INNS is facilitated by human mediated routes and activities called "Pathways", for example, shipping, recreational boating and aquaculture.
- Aquaculture is recognised as a key pathway for the introduction and spread of INNS, with potential for aquaculture activity to move both animals (as eggs and in their larval, juvenile and adult life stages) and seaweed (as fragments or spores).
- INNS can be introduced and spread via biofouling on aquaculture equipment, biofouling on stock and on materials moved with stock, escapes of stock (if an INNS) and staff movement.
- Reducing the impact of INNS is commonly approached through efforts to prevent their spread at the pathway level.
- Legislation and policy related to the introduction and spread of INNS exists, covering both general activities and activities specific to aquaculture.
- The objectives of this Pathway Action Plan (PAP) are to:
    - Outline the INNS biosecurity risks associated with the aquaculture pathway.
    - Identify key marine INNS associated with the aquaculture pathway.
    - Provide aquaculture stakeholders with a series of scalable actions that could be implemented to reduce the risk of introducing and spreading marine INNS via aquaculture activities.
- This PAP is intended to complement and enhance the existing biosecurity actions undertaken by the aquaculture sector.
- Stakeholders are those that use, benefit from, or are responsible for (e.g. managing, protecting or regulating) the marine environment. Here, this includes relevant authorities and statutory bodies, aquaculture businesses and site managers, and those involved in the aquaculture operations listed below.
- This PAP is intended to be applicable to aquaculture across all Welsh marine areas, including, but not limited to:
    - intertidal shellfish, culture using trestles and/or poles;
    - intertidal ground laid shellfish culture;
    - rearing of shellfish in hatcheries;
    - intertidal planted seaweed culture;
    - subtidal seaweed aquaculture using ropes and/or rafts;
    - subtidal shellfish aquaculture using ropes and/or rafts; and
    - subtidal ground laid shellfish aquaculture.
- This PAP outlines seven components of biosecurity focus for the aquaculture pathway within Welsh marine areas:

1. Understanding roles and legal responsibilities
2. Information and guidance on INNS and biosecurity
3. Raising awareness
4. Biosecurity processes and procedures
5. Biosecurity facilities
6. Monitoring and reporting
7. Collaborative working

- Example practical (control and management) actions for aquaculture operators are provided, along with an example protocol for mussel seed movements and considerations for site maintenance and construction operations.
- This plan is intended to be used in support of the associated Species Action Plans (SAPs), and Biosecurity Action Plans (BAPs).

This PAP acknowledges that authorisation as an Aquaculture Production Business (APB) includes the completion of a Biosecurity Measure Plan for the prevention/reduction of disease. Although overlap will inevitably occur, this PAP is not intended to override any of the requirements or associated guidance provided under the Aquatic Animal Health (England and Wales) Regulations 2009.

Preface

Safeguarding Wales's marine environment and native biodiversity requires robust biosecurity measures to prevent the spread and impact of invasive non-native species (INNS). The guidance in this Pathway Action Plan outlines actions and guidance to support stakeholders with their biosecurity efforts, with the aim of making Welsh marine aquaculture more sustainable.

It is acknowledged that no single activity is solely responsible for the spread of INNS and all users of the marine environment are encouraged to take the time to understand more about this threat and how they can contribute to tackling it.

Stakeholders are encouraged to share this plan, the guidance within it, the actions that they choose to undertake and to raise awareness of biosecurity. Collective effort is ideal, but individual actions are equally vital. Proactive steps by stakeholders, even when taken independently, strengthen national INNS biosecurity and help to protect our marine environment — every action counts.

The significance of this issue is recognised by Natural Resources Wales, who commissioned, and will manage this plan under a wider framework of INNS biosecurity planning.

Background

What are Invasive Non-Native Species (INNS)?

Non-native species (NNS) are plants, animals or pathogens that do not naturally occur in an area but have been moved there, by human activities (either accidentally or deliberately). NNS are also sometimes referred to as “alien species”, “non-indigenous species” or “exotic species”. Most NNS do not cause issues within the area where they have been introduced. However, 10-12% cause significant environmental, social or economic impacts. These are known as Invasive Non-Native Species (INNS) and, in Wales, include the American slipper limpet, carpet sea squirt and Japanese wireweed, among many others. The impacts of INNS include threats to biodiversity, habitat alteration, fouling underwater structures (including aquaculture equipment, navigational aids and piers) and the introduction of diseases. The impacts of INNS (in all environments including marine) are estimated to cost the British economy £4 billion per year, of which, £499 million per year is attributed to impacts in Wales (see the 2023 Eschen paper). Marine INNS are resilient and often capable of surviving harsh and variable conditions, making them particularly challenging to manage. Many species can endure high levels of drying, temperature fluctuations, and low nutrient availability, allowing them to persist in damp conditions for extended periods. For instance, mussels, barnacles and algae can remain viable (i.e., still able to live and/or reproduce) when attached to damp equipment, nets or boat hulls, even after days or weeks out of the water. The resilience enables them to travel long distances, hitchhiking on fishing gear, recreational boats, or clothing/equipment.

What are pathways?

The mechanisms and routes by which INNS are moved from one location to another by humans are termed “pathways”. This movement of species by humans, accidentally or deliberately, allows INNS to overcome natural barriers that would otherwise prevent them from spreading between their native and non-native ranges, e.g., an ocean. For instance, Pacific oysters, native to Japan, would not be able to reach UK waters through natural spread, but when introduced into UK waters by human activity can survive and establish as the environmental conditions in the UK are compatible with their native range. Animals can be moved as eggs and in their larval, juvenile and adult life stages. Seaweed can be moved as fragments or spores (their reproductive structures). Larvae can be planktonic (drift with currents, unable to propel themselves against water movement) or free-swimming (can actively move and maintain their position in the water column).

Pathways are broadly classified as two types:

1) Pathways of initial introduction: Those which transfer NNS to regions or locations that are geographically separate and isolated from their native range (referred to as “introduction(s)” in this document). An example of this would be the movement of transoceanic vessels.

2) Pathways of further spread: These facilitate the movement of NNS populations beyond their initial introduction point to a wider area (referred to as “spread” in this document):

    a. Facilitating the short-range dispersal of an NNS population within a single habitat or location (e.g. paddle boarders spreading a seaweed within a bay), or

    b. Facilitating regional spread where some small barriers exist (e.g., the movement of recreational boats between two nearby but separate harbours).

The frequency and magnitude of pathways in the marine environment have been increasing since the 1800s with the beginning of rapid globalisation. A significant movement of marine INNS has been through the transoceanic voyages and shipping that has long supported growing global economies and international supply chains. For more information on other pathways in the marine environment, please see the other Welsh Pathway Action Plans. Links can be found on the Wild Seas Wales website.

Vectors are the specific, discrete parts of a pathway (i.e. the means within a pathway) that facilitate the movement of INNS from one location to another. Vectors within the aquaculture pathway could include the escape of a cultured INNS from the aquaculture site, INNS hitchhiking on the cultured species or INNS-fouled equipment that is brought to a site. For boating pathways, vectors could include INNS fouling the boat hull or INNS being taken up in water-retaining features (e.g., bilge or ballast tanks). The relationship between pathways and vectors in the marine environment is illustrated in Figure 1.

Natural spread of INNS e.g., larvae distributed along a coastline by tides and currents, may also occur following introductions. However, unlike the spread caused by human activities, natural spread is generally limited by the inherent barriers between locations. Natural spread is generally gradual and organic (i.e. slow outward spread from a point-source of introduction). Although natural spread is more challenging to manage, improved biosecurity procedures, particularly at high-risk/vulnerable sites, can reduce the risk of impact and improve the chances that introductions are detected early.

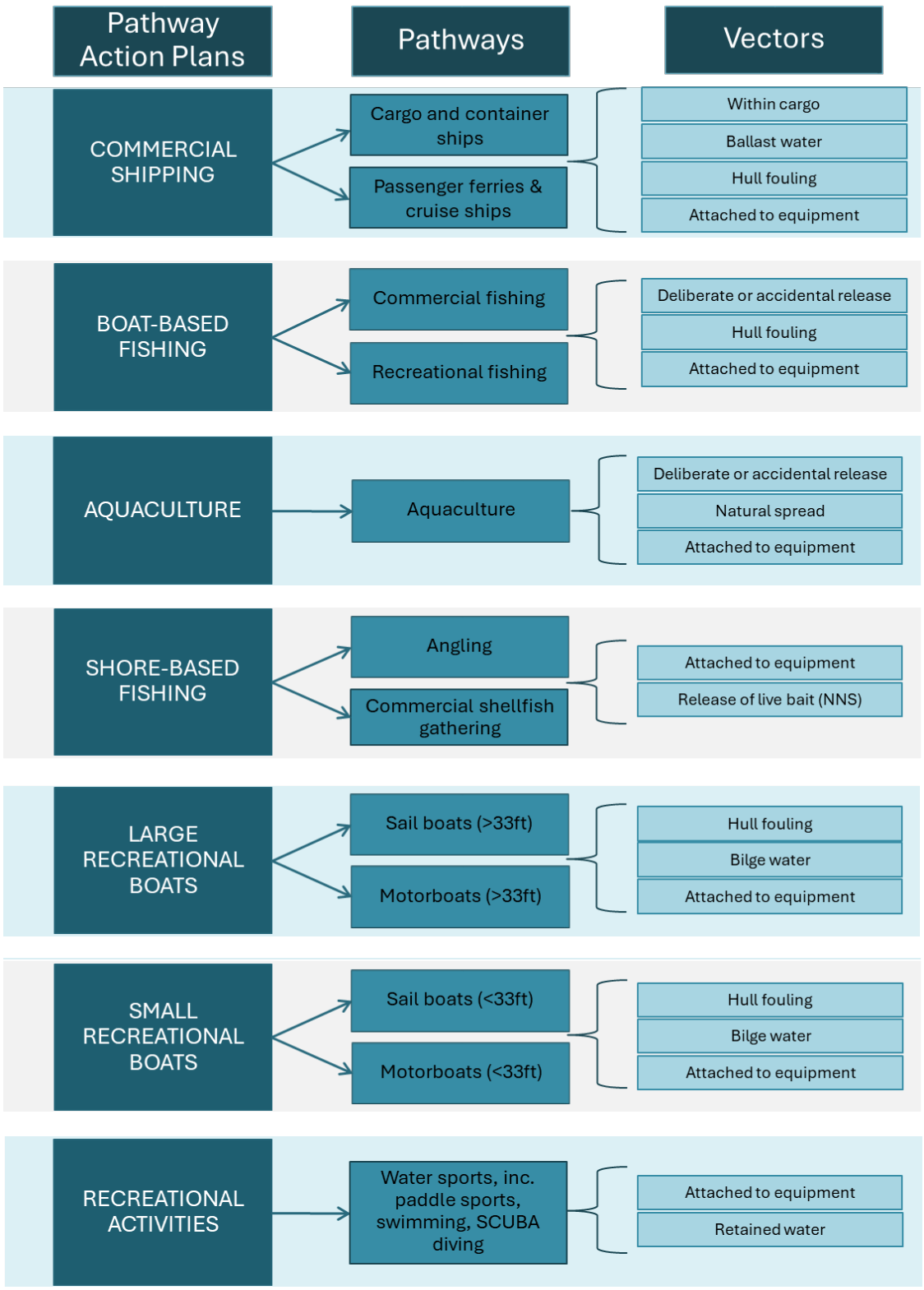


Figure 1: An overview of the Pathway Action Plans that have been developed for Wales, and the vectors associated with the pathways. Note that the list of vectors is not exhaustive.

What is biosecurity?

Biosecurity measures are actions, procedures and behaviours put in place to reduce the risk of INNS introduction and spread into, within and outside of a given area. Biosecurity measures should be realistic, pragmatic and cost-effective. Preventing the introduction and spread of INNS is by far the most effective way to reduce the impact of INNS. Eradication and control of INNS is often not possible in the marine environment and any attempts are more costly, difficult, and time-consuming compared to preventing the arrival and establishment of INNS in the first place. This is especially true in the marine environment, where eradication is near impossible once INNS become established.

A biosecurity framework: what is the context for this Pathway Action Plan?

This Pathway Action Plan forms part of a biosecurity planning framework commissioned and endorsed by Natural Resources Wales. The driver behind the framework is the wider goal of improving the condition of and increasing biodiversity in protected marine sites. Within the marine environment, this goal includes reducing the introduction and spread of INNS. The Species Action Plans (SAPs) and the Pathway Action Plans (PAPs) produced for this framework are intended to provide a basis for biosecurity planning for all marine sites throughout Wales, as well as presenting standalone guidance for pathway management. Figure 2 shows the relationships between each of the action plans.

Pathway Action Plans (PAPs) describe the pathway and list possible actions that could be undertaken to address the risk of the introduction and spread of INNS via that pathway into or around Wales. Links to the other PAPs can be found on the Wild Seas Wales website.

Species Action Plans (SAPs) describe priority INNS and list possible actions that could be undertaken to address the introduction and spread of that species into or around Wales. Links to the SAPs can be found on the Wild Seas Wales website.

Biosecurity Action Plans (BAPs) are site-specific and can be scaled as appropriate. A BAP can be produced for a whole region (i.e. as has been done for the Pembrokeshire Marine, Cardigan Bay, Menai Strait and Conwy Bay and Carmarthen Bay and Estuaries Special Areas of Conservation (SACs)) or for an individual port, harbour or aquaculture site. They will identify the pathways relevant for that site and the species at or near the site that are of concern. The actions listed in the PAPs and SAPs are relevant to all stakeholders (see Key stakeholders) and should be considered and incorporated into a site's BAP. Due to the wide breadth and scale of the different stakeholder groups, the scope of these actions is equally broad. It is therefore important that individual stakeholders review their activities and use of the site to decide which of the biosecurity actions are applicable and practicable. Individual aquaculture site level BAPs were not developed as part of this project, however, the information within this PAP (and the other PAPs and SAPs) could be used to produce one.

Biosecurity To-Do-List trackers have been created to make it easier for stakeholders to log what actions they plan to carry out and track what progress is being made on each action. The need for using to-do-list trackers will be dependent on the scope and scale of the BAP. For example, the BAPs produced for the Welsh SACs cover such large areas that it is necessary to provide individual stakeholders with an additional support tool that makes it easier to log and track their actions. The tracker also enables NRW, as the SAC BAP manager, to effectively oversee the implementation of biosecurity within each SAC, highlighting progress and pinpointing where further assistance or support may be needed. This approach is also intended to facilitate coordinated monitoring and collaborative efforts to share and enhance biosecurity practices between stakeholders. Biosecurity planning at smaller scales (e.g. an individual port or aquaculture facility) are unlikely to require a BAP and a to-do-list tracker in parallel. Stakeholders can decide which is the most appropriate method for facilitating their biosecurity efforts.

Although we encourage aquaculture operators to engage within this framework, their existing disease-focused biosecurity efforts and procedures may not require the creation of standalone BAPs or the use of to-do-list trackers. **Operators are encouraged to read this PAP and modify/support their existing procedures based on the recommendations presented.** It is worth acknowledging that statutory authorities, including NRW, will also be progressing actions under this framework.

We encourage aquaculture operators to consider the benefits of improved biosecurity to both the sustainability and profitability of the industry.

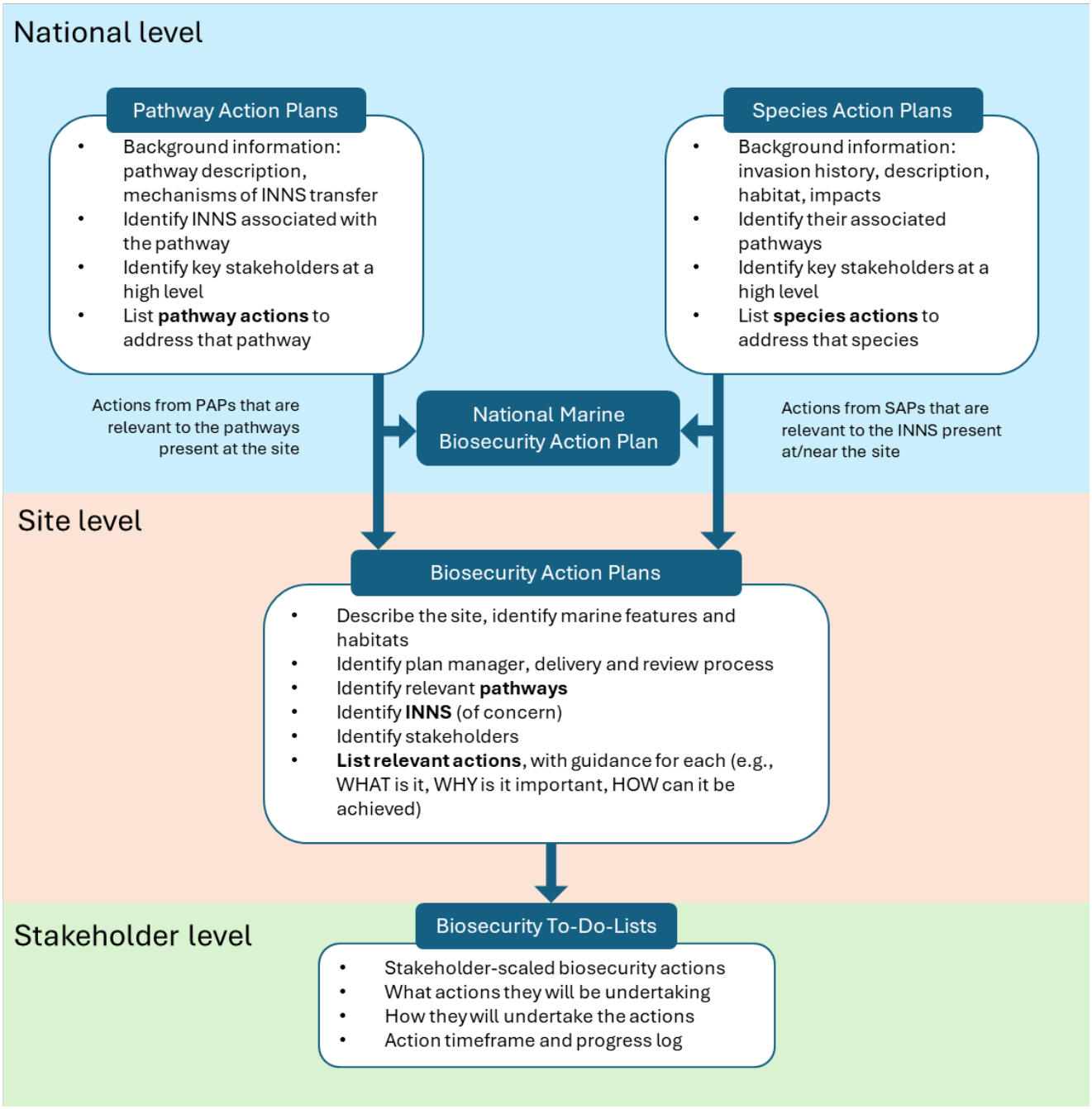


Figure 2: A flowchart showing the relationship between the Pathway Action Plans, Species Action Plans and the Biosecurity Action Plans created for the Natural Resources Wales Biosecurity Planning Project with APEM Ltd.

Scope, aims and objectives

Scope

This Pathway Action Plan (PAP) is intended to be applicable to aquaculture across all Welsh marine areas. Here, aquaculture includes, but is not limited to:

- Intertidal shellfish, culture using trestles and/or poles
- Intertidal ground laid shellfish culture
- Rearing of shellfish in hatcheries
- Intertidal planted seaweed culture
- Subtidal seaweed aquaculture using ropes and/or rafts
- Subtidal shellfish aquaculture using ropes and/or rafts
- Subtidal ground laid shellfish aquaculture

This document, and the biosecurity measures outlined within it, are intended to be applicable to aquaculture operators and the relevant wider stakeholder groups. Please see Key stakeholders for more information. The actions encompass several dimensions of INNS management for the pathway including:

- Strategies for effective INNS biosecurity
- Strategies to enable early detection and quick reaction to new records
- Coordination of efforts, resource sharing and collaboration
- Research, development and innovation
- National policy and regulatory frameworks

Aim

The overall aim of this PAP is to reduce the risk of the introduction and spread of marine INNS via aquaculture.

This document aims to complement the existing national work on aquaculture biosecurity (for further information see legislation) providing aquaculture specific information to aid a pathway-based approach to biosecurity. It also seeks to put forward actions that can be applied at national (Welsh), regional and local levels (see Key stakeholders). The goal is to use existing communications and resources wherever available and adapt them to fit specific requirements. This approach aims to avoid any duplication or unnecessary additional effort. This will facilitate a consistent approach to biosecurity for this pathway across Wales.

Objectives

- Outline the INNS biosecurity risks associated with aquaculture.
- Identify marine INNS associated with the aquaculture pathway.

- Provide a list of clear and practical biosecurity actions to address the pathway. These can subsequently be scaled, as appropriate, and applied to a specific site and its stakeholders.

The aquaculture pathway

Aquaculture refers to the farming of aquatic organisms, such as fish, shellfish, and plants, for food, recreation, and scientific purposes. It is a key seafood production sector within the Welsh marine areas around the country's coastline. Mussel and oyster production business are the main aquaculture activities within Welsh marine areas. Other organisms, such as seaweeds are also cultivated or collected.

In the marine environment, aquaculture is recognised as a pathway for the introduction and spread of INNS, with potential for aquaculture activity to move both animals (as eggs and in their larval, juvenile and adult life stages) and seaweed (as fragments or spores). There are multiple vectors by which INNS can be spread via the aquaculture pathway. These include:

- biofouling on aquaculture equipment (including boats, trestles and tractors);
- biofouling on stock (e.g., hitchhikers) when brought on site or transferred off site;
- biofouling on materials that are moved with stock (e.g., packing material and containers);
- viable INNS transferred in water along with stock;
- escapes of stock (if an INNS); and
- staff movement between sites (e.g., hitchhikers on personal protective equipment (PPE) and vehicles).

Biofouling (or biological fouling) is the accumulation and growth of organisms (plants, animals, bacteria and detritus), including INNS, on underwater surfaces. This includes all surfaces and hard to reach areas and crevices that are in contact with the water. In the marine environment, common biofouling organisms include sea squirts, barnacles and sponges.

The first stage of fouling is the formation of a biofilm on the surface, which is a thin layer of microalgae, bacteria and small particles. The presence of this biofilm facilitates the further colonisation of the surface by other marine organisms. It is important to note that the species found on underwater surfaces are not necessarily INNS, but there are many INNS known to accumulate as biofouling or live among biofouling organisms.

Biofouling can especially accumulate if equipment and other underwater surfaces remain static in the water for a prolonged period of time. Equipment used in aquaculture that could be fouled includes boats, tractors and equipment used for cultivation (e.g., ropes, dredges, trestles, and wire or plastic mesh containers) etc. INNS can also foul or attach to staff PPE such as boots, waders, dry suits and buoyancy aids.

The movement of fouled equipment between sites can risk spreading INNS to a new location. If equipment does not move beyond the cultivation site, the biosecurity risk is reduced; however, biofouling that is left unchecked on submerged equipment can also be a source of INNS spreading beyond the cultivation site through natural means (i.e. on ocean currents).

Movement of shellfish (and packaging materials and water) onto the cultivation site, if fouled or contaminated with INNS, could also lead to the introduction of INNS into the cultivation site. Similarly, INNS may be spread off site if exported harvested stock is fouled or contaminated (including packing materials and water) with INNS.

The risk of INNS introduction onto a site as a result of stock movements is likely to be reduced if the stock being moved is produced in a controlled or sterile environment.

While good practice guidance exists to reduce the biosecurity risk posed by stock movements (see Useful resources), these practices are not infallible, due to the challenges of detecting and identifying INNS. Therefore, a holistic and robust approach to biosecurity is required to minimise risk. Alongside this PAP, industry best practice should be used, and any licencing conditions adhered to.

Though current legislation prevents the cultivation of INNS if the risk of escape into the wild cannot be managed, commercially cultivated INNS do exist as a result of historic permissions. For example, the Pacific oyster (classified as an INNS) is legally cultivated in the UK and is a commercially important species. Despite deployment of methods to reduce the risk of establishment and spread, such as the cultivation of triploid Pacific oysters, the escape of viable stock and human mediated spread remains a potential risk.

Vessel with heavy fouling, including Japanese kelp (*Undaria pinnatifida*) © GB NNSS.

How do INNS impact aquaculture operations?

INNS are a major problem for aquaculture, leading to increased financial costs and reduced productivity. It is estimated that 10-30% of annual aquaculture operating costs result from the cleaning and maintenance required to manage INNS. The impacts of INNS on aquaculture may be extensive and varied and include the following:

- **Increased drag and reduced efficiency of equipment**: Biofouling on boats increases drag, making vessels less efficient, leading to higher fuel costs. On aquaculture gear, it adds weight and drag, which can lead to equipment damage.
- **Competition for resources**: INNS can compete with aquaculture stock for space and nutrients. INNS can also reduce water flow which may impair oxygen and food supply, affecting stock health, growth and condition.
- **Barriers to larval settlement**: Larval attachment and settlement on substrate may be reduced or blocked if the substrate is fouled by INNS. This reduces the efficiency of wild spat capture and may decrease cultivation yields and profitability.
- **Direct impact on shellfish**: Biofouling organisms can physically damage shellfish stock, obstruct feeding, and compromise growth and overall condition. This, in turn, reduces the quality and marketability of the stock. The appearance and health of shellfish are critical to their sale value, with fouling negatively affecting both. Additionally, biofouling may lead to restrictions on moving stock between locations due to presence of INNS.
- **Predation, parasites and pathogens:** INNS can further threaten aquaculture by directly preying on stock or introducing pathogens and parasites, leading to mortalities and reduced stock condition.

Top photo: Carpet sea squirt, *Didemnum vexillum* growing on oyster trestles © Joe Ironside.
Bottom photo: Stack of slipper limpets, *Crepidula fornicata* growing on a whelk shell © Charlotte Colvin.

Relevant INNS for aquaculture

The tables below present INNS that are likely to spread via aquaculture. Table 1 describes High and Medium risk INNS from the Welsh Priority Monitoring and Surveillance List (WPMSL) that are known to be present and breeding in Wales. Table 2 describes INNS that are not currently recorded as present in Wales (known as horizon species) but should be monitored for. It is important to identify species that may be on the horizon so that appropriate biosecurity actions can be put in place to prevent their introduction, or surveillance programmes can be implemented to aid timely detection and response. Some species are on the horizon for the UK and some are on the horizon for Wales. These species represent some of the most likely to be transported via aquaculture. Note that this is not an exhaustive list, as there are other INNS known to be transported by aquaculture that are not listed as High or Medium risk on the WPMSL.

The current distributions of INNS around Wales (and the UK more broadly) can be viewed by searching the database and maps on the National Biodiversity Network Atlas (NBN Atlas).

An overview of the different lists of INNS that are of interest to Wales can also be found on the NBN Atlas. The current distribution of INNS included on those national lists can be found on the Wales INNS Portal.

Further information and links to resources developed to aid identification of INNS are available below. Further species-specific information is also available from the searchable GB NNSS Information Portal.

Table 1. High and Medium risk INNS established in Wales that are likely to spread via aquaculture.

INNS Name	Potential impacts	Image	Additional information
American jack knife clam (*Ensis leei*)	May compete for space and food with other shellfish. High densities of the species have the potential to damage trawling equipment or become a health and safety hazard to aquaculture operators.	 Photo credit: Larry Jensen [CC BY, via iNaturalist]	Larvae may be in water that is transported with shellfish. Larvae are planktonic for approx. 4 weeks (high dispersal risk). Inhabit low intertidal areas along open coastal, lagoon and estuarine habitats. Salinity tolerance 25-35ppt. For further information see the GB NNSS Information Portal and NBN Atlas.

INNS Name	Potential impacts	Image	Additional information
American slipper limpet (*Crepidula fornicata*)	Changes in hydrodynamics, and therefore food and oxygen availability; food and space competition with shellfish (including prevention of spat settlement); reduction of shellfish larvae (via predation); change in local biodiversity.	 Photo credit: Elizabeth Green [CC BY, via iNaturalist].	Juveniles and adults can foul shellfish; larvae may be in water that is transported with shellfish. Larvae are planktonic for 4-5 weeks (high dispersal risk). Breeding can occur between Feb. and Oct. but peaks in May and June. Spawning seen even at temperatures as low as 7°C. For further information see the GB NNSS Information Portal, Risk Assessment and NBN Atlas A link to the Species Action Plan can be found on the Wild Seas Wales website.

INNS Name	Potential impacts	Image	Additional information
Carpet sea squirt (*Didemnum vexillum*)	Excessive weight and drag on infrastructure; changes in hydrodynamics, and therefore food and oxygen availability; food and space competition with shellfish (including prevention of spat settlement); mortality of shellfish due to smothering; change in local biodiversity.	 Photo credit: Javier [CC BY, via iNaturalist]	Individual zooids or colonies can foul shellfish and aquaculture equipment; larvae or fragments may be in water that is transported with shellfish. Larvae are planktonic for a few hours (low dispersal risk). Fragments are viable for up to 30 days (high dispersal risk). Tolerant to temperatures between 2-24°C and salinities >26ppt. Reproduction occurs between 14-20°C. For further information see the GB NNSS Information Portal, Risk Assessment, NBN Atlas and the 2023 alert poster. A link to the Species Action Plan can be found on the Wild Seas Wales website.

INNS Name	Potential impacts	Image	Additional information
Chinese mitten crab (*Eriocheir sinensis*)	Erosion of river / stream banks; affect fisheries by damaging nets, killing netted fish, consuming bait & damaging gear; clog water intake pipes; compete for food & space and predate on native species in freshwater & marine; burrowing activities affect water quality.	 Photo credit: The Food and Environment Research Agency [via GB NNSS]	Juveniles may briefly live on or between shellfish and equipment; larvae may be in water that is transported with shellfish. Reproduction occurs in brackish/marine waters (15-30 ppt salinity). Larvae are planktonic in the marine environment for up to 2 months (high dispersal risk). For further information see the GB NNSS Information Portal, Risk Assessment and NBN Atlas. A link to the Species Action Plan can be found on the Wild Seas Wales website.

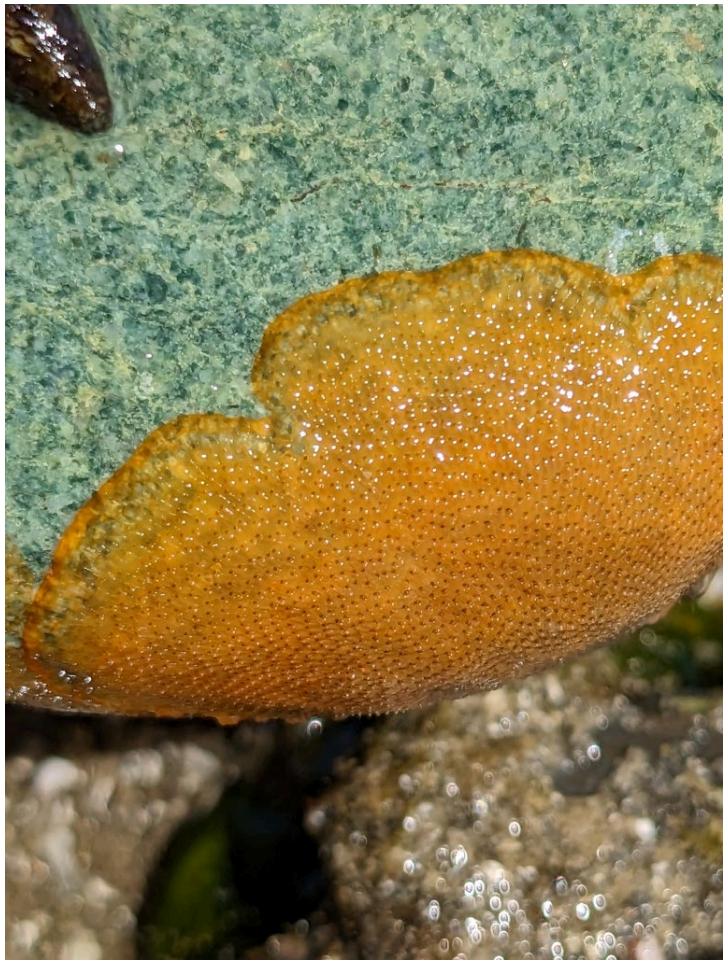
INNS Name	Potential impacts	Image	Additional information
Compass sea squirt (*Asterocarpa humilis*)	Excessive weight and drag on infrastructure; changes in hydrodynamics, and therefore food and oxygen availability; food and space competition with shellfish (including prevention of spat settlement); change in local biodiversity.	 Photo credit: Bernard Picton [CC BY, via iNaturalist]	Adults can foul shellfish and aquaculture equipment. Hatched larvae are retained by the mother so natural dispersal risk is low. For further information see the GB NNSS Information Portal and NBN Atlas.

INNS Name	Potential impacts	Image	Additional information
Devil's tongue weed (*Grateloupia turuturu*)	Outcompetes native algae and seagrasses, leading to changes in local ecosystems. Rapid growth and dense mats can smother other marine life, reducing biodiversity. Alters habitats by changing the structure of the seafloor, which affects the species that rely on these habitats for food and shelter. Can have cascading effects throughout the marine food web. Negatively affect fisheries and aquaculture operations by the fouling of nets, ropes, and other equipment. It can also create unfavourable conditions for aquaculture.	 Photo credit: Elena_Sherehora [CC BY, via iNaturalist]	Strands may attach to shellfish or be entangled in aquaculture equipment; spores (their reproductive structures) and fragments may be in water that is transported with shellfish. Spores can develop at temperatures ranging between 15-20°C. Developed strands have a wide temperature tolerance (4-29°C). For further information see the GB NNSS Information Portal and NBN Atlas.

INNS Name	Potential impacts	Image	Additional information
Japanese Kelp / Wakame (*Undaria pinnatifida*)	It potentially reduces local biodiversity, by outcompeting and displacing native species. Dense forests of this species can foul fishing gear and aquaculture equipment. Its dense growth can also affect the availability of space and resources for commercially valuable species.	 Photo credit: Steve Kerr [CC BY, via iNaturalist]	Strands/fronds may attach to shellfish or be entangled in aquaculture equipment; spores may be in water that is transported with shellfish. Fertilisation can occur between 10-15°C with optimum growth for spores between 15-20°C. Spores can survive in temperatures between -1 and 30°C. Spores can be vegetative and remain viable for up to 2 years under certain conditions. For further information, see GB NNSS Information Portal, Risk Assessment and NBN Atlas.

INNS Name	Potential impacts	Image	Additional information
Japanese skeleton shrimp (*Caprella mutica*)	Likely to displace other native amphipod species & potentially compete with sessile suspension feeders for food.	 Photo credit: Lucinda Lintott [some rights reserved]	There is minimal movement of adults, so they are predominantly moved as 'hitchhikers'. Adults (often <50mm) and juveniles may live among fouling communities on shellfish and equipment; adults and juveniles may be in water that is transported with shellfish or attached to the shellfish or equipment itself. They have a wide temperature tolerance range (-2-28°C) but cannot tolerate low salinities (<18ppt). See GB NNSS Information Portal, Risk Assessment and NBN Atlas.

INNS Name	Potential impacts	Image	Additional information
Japanese wireweed (*Sargassum muticum*)	Can interfere with recreational & commercial use of waterways, especially when detached & forming large floating masses; known for fouling fishing gear & boat props, as well as blocking intake pipes of aquaculture facilities; known to alter habitats; impacts to subtidal native assemblages through overgrowing & shading underlying species, with particular concern for seagrasses.	 Photo credit: Susan Marley [CC BY, via iNaturalist]	Strands/fronds may attach to shellfish or be entangled in aquaculture equipment; spores or fragments may be in water that is transported with shellfish. Fragments viable for up to 3 months. Wide tolerances of temperature (10-30°C) and salinity (7-34ppt). For further information see the GB NNSS Information Portal, Risk Assessment and NBN Atlas.

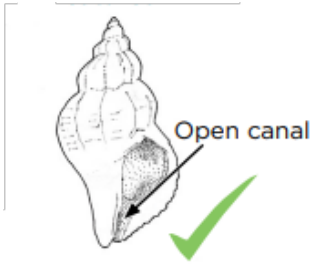
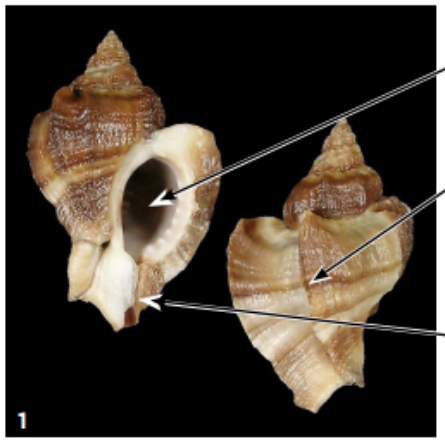
INNS Name	Potential impacts	Image	Additional information
Orange ripple bryozoan (*Schizoporella japonica*)	Replaces similar native species through competition; increases habitat complexity, facilitating colonisation by other INNS.	 Photo credit: B Staffan Lindgren [CC BY, via iNaturalist]	Colonies can foul shellfish and aquaculture equipment. Short free-swimming larval stage (approx. 2 days) so natural dispersal risk is low. For further information, see GB NNSS Information Portal and the NBN Atlas.

INNS Name	Potential impacts	Image	Additional information
Orange striped anemone (*Diadumene lineata*)	Can be a fouling organism on vessels, aquaculture & fishing equipment & other artificial structures; potentially decreases local biodiversity through outcompeting native species; may impede growth of shellfish and their ability to feed. Suggestion that the species predates the larvae of blue mussels and oysters.	 Credit: Smithsonian Environmental Research Center [CC BY-SA 2.0, via Wikimedia Commons]	Individuals can foul shellfish and aquaculture equipment. Free-swimming larval stage of up to 2 weeks so risk of natural dispersal. Temperature range of 14-24°C and salinity range of 18-34 ppt. For further information, see GB NNSS Information Portal and the NBN Atlas.

INNS Name	Potential impacts	Image	Additional information
Red ripple bryozoan (*Watersipora subatra*)	Tolerant of copper and mercury in antifouling paint, thus easily foul vessel hulls; replaces similar native species through competition; increases habitat complexity, facilitating colonisation by other INNS.	 Photo credit: Jacqui Geux [CC BY, via iNaturalist]	Colonies can foul shellfish and aquaculture equipment. Short free-swimming larval stage (less than 1 day) so natural dispersal risk is low. Wide temperature tolerance (12-28°C) and salinity range (25-49ppt). For further information see the GB NNSS Information Portal and NBN Atlas.

INNS Name	Potential impacts	Image	Additional information
Trumpet tubeworm *(Ficopomatus enigmaticus)*	Excessive weight and drag on infrastructure; changes in hydrodynamics, and therefore food and oxygen availability; food and space competition with shellfish (including prevention of spat settlement); change in local biodiversity.	 Photo credit: Cricket Raspet [CC BY, via iNaturalist]	Adults can foul shellfish and aquaculture equipment; larvae may be in water that is transported with the shellfish. Planktonic larval stage 1-3 months (high dispersal risk). Minimum water temperature of 18°C needed for reproduction. Wide salinity tolerance (1.6-55 ppt) but preference for brackish environments. For further information see the GB NNSS Information Portal and NBN Atlas. A link to the Species Action Plan can be found on the Wild Seas Wales website.

Table 2. Examples of INNS that are not currently recorded as present in Wales (horizon species) but are likely to spread and/or impact aquaculture.

Horizon INNS name	Potential impacts	Image	Additional information
HORIZON SPECIES: American and Japanese oyster drills (*Urosalpinx cinerea* & *Ocinebrellus inornatus*)	Predator of shellfish including commercially important species, resulting in huge economic loss.	   Top: American oyster drill: Photo credit: Bill Frank [via GB NNSS]. Diagram credit: Guy Baker. Bottom: Japanese oyster drill: Photo credit: G.T. Poppe	They may be transported attached to shellfish (as larvae which emerge from eggs, or small juveniles) which are being translocated. No planktonic larval stage for either species so natural spread risk is low. For further information on *U. cinerea* see the GB NNSS Information Portal, Risk Assessment and NBN Atlas. For further information on *O. inornatus* see the GB NNSS Information Portal, Risk Assessment and NBN Atlas. A link to the Species Action Plan can be found on the Wild Seas Wales website.

Horizon INNS name	Potential impacts	Image	Additional information
HORIZON SPECIES: Veined rapa whelk (*Rapana venosa*)	Predator of shellfish including commercially important species, has the potential to decimate bivalve fisheries, with associated economic loss.	 Photo credit: H. Zell [via Wikimedia]	Larvae may be in water that is transported with commercial shellfish. Planktonic larval phase of 24-80 days (high dispersal risk). Successful establishment of reproductive populations seen to occur between 18-26°C. For further information, see the GB NNSS Information Portal, Risk Assessment and the NBN Atlas.

INNS, Pathways and the law

The following points provide a brief summary of relevant legislation (at time of writing):

- Pathway management and the development of pathway action plans are specifically mentioned under the EU Regulation (1143/2014) on the prevention and management of the introduction and spread of invasive alien species. This regulation was retained in domestic law under the European Union (withdrawal) Act 2018 as the Invasive Alien Species (Enforcement and Permitting) Order 2019.

- The Wildlife and Countryside Act 1981 makes it an offence to release or allow to escape into the wild any plant or animal which is not ordinarily resident in Great Britain (i.e. non-native) and is not a regular visitor to Great Britain in a wild state (i.e. migratory).

- The Marine Strategy Regulations 2010 transpose into domestic law the EU Marine Strategy Framework Directive. The Directive aims to reduce human impacts on the marine environment, including INNS. The programme of measures is intended to reduce the introduction and spread of INNS. INNS pathway management helps to deliver the 2010 Regulations.

- The Water Environment (Water Framework Directive) (England and Wales) Regulations 2017 transpose into domestic law the EU Water Framework Directive. The Directive establishes a framework for national measures to achieve or maintain a good ecological status, including transitional and coastal waters. While INNS are not specifically mentioned within the 2017 Regulations they could affect the ecological status of waterbodies. Pathway management is a key aspect of managing the potential spread of INNS.

Aquaculture-specific legislation

- Marine and Coastal Access Act (2009): This act regulates marine activities, including aquaculture, across the UK. It provides a framework for sustainable management of the marine environment through fisheries and aquaculture, marine licensing, marine planning, and conservation powers.

- The Sea Fisheries (Shellfish) Act 1967: provides local shellfishery fisheries management powers managed through the use of Several and/or Regulating Orders. These orders give certain rights to manage shellfish fisheries within prescribed areas, often to allow for sustainable management and cultivation.

- The Molluscan Shellfish (Control of Deposit) Order 1974: allows the Welsh Government to control the deposition of shellfish, particularly when shellfish are being moved between different locations, providing a mechanism for risk reduction of this pathway/vector.

- Aquatic Animal Health (England & Wales) Regulations 2009 and The Animals, Aquatic Animal Health, Invasive Alien Species, Plant Propagating Material and Seeds (Amendment) (EU Exit) Regulations 2020 managed and enforced by the Fish Health

Inspectorate require Aquaculture Production Businesses (APBs) to register and be authorised to operate within marine and freshwater environments primarily to control the spread of disease.

    - For a shellfish farm to be authorised, a Biosecurity Measures Plan should be put in place to control the spread of diseases. This is a standard requirement under the Aquatic Animal Health (England & Wales) Regulations to ensure that disease risks are managed. The regulation controls fish and shellfish diseases, it contains no specific measures to enforce control of the spread of shellfish pests, including INNS.

- Alien and Locally Absent Species in Aquaculture (England & Wales) Regulations 2011: require the provision of aquaculture permits to reduce the introduction of INNS for certain aquaculture species and biosecurity to manage the aquaculture pathway.

Biosecurity to Manage the Aquaculture Pathway

The following sections present information on existing biosecurity within the aquaculture sector as well as actions that, if undertaken, would improve biosecurity in this sector and, ultimately, reduce the risk of INNS impacting stakeholders and aquaculture operations.

Who are the key stakeholders?

Within the context of this PAP, a stakeholder is anyone who uses, benefits from or is responsible for (e.g. managing, protecting or regulating) the marine environment.

Biosecurity for aquaculture requires engagement and actions taken at national, regional and local scales by specific stakeholders including, but not limited to individuals, businesses, site managers, statutory bodies, and authorities. To note, the term “authorities” here refers to bodies with powers to introduce, amend and enforce regulations, legislation and policy.

For the successful implementation of the actions recommended in this PAP and across the biosecurity framework, stakeholders must work together to engage, support and secure resources where needed.

Examples of relevant stakeholders include:

Authorities

- Government departments, organisations and agencies (e.g., Welsh Government)
- Regulatory bodies (e.g., Natural Resources Wales)
- County councils and local authorities
- National Park Authorities
- Fish Health Inspectorate (FHI)

National stakeholders

- Managing bodies for protected sites (e.g., National Trust)
- Aquaculture governing bodies (e.g., Seafish, Menai Strait Fishery Order) Management Association (MSFOMA)
- Environmental charities and Non-Governmental Organisations (NGOs) (e.g., the Marine Biological Association, The Wildlife Trusts)
- Major landowners (e.g., the Crown Estate)
- National associations (e.g., Welsh Fishermen's Association - Cymdeithas Pysgotwyr Cymru (WFA-CPC), Welsh Aquaculture Producers' Association (WAPA), Aquaculture Industry Wales)

Local stakeholders

- Harbour authorities
- Aquaculture facility operators
- Stakeholders at point of sale (e.g., seafood wholesalers)

Existing biosecurity in aquaculture

This PAP acknowledges that**:**

- authorisation as an Aquaculture Production Business (APB) includes the satisfactory completion of a Biosecurity Measure Plan for the prevention/reduction of aquatic animal disease; and

- that aquaculture operators and APBs may already be implementing procedures and protocols that reduce the risk of INNS spread associated with their operations.

This PAP, and the wider biosecurity framework (within which this PAP sits) are intended to complement and enhance the existing biosecurity actions undertaken by the aquaculture sector (some examples included below). The INNS biosecurity actions recommended here do not replace the legal requirements or associated guidance, particularly with respect to animal health.

Aquaculture site biosecurity planning

Site-specific biosecurity action planning is an important tool to help ensure that a thorough and planned approach to biosecurity is taken. The framework associated with this PAP allows for biosecurity planning to be scaled as deemed appropriate by stakeholders. For instance, aquaculture operators could create aquaculture site-specific INNS BAPs, to-do-list-trackers, or carry out updates to existing disease biosecurity measures plans to consider the INNS risks posed by their site or activity. Whatever scale or method is chosen, planning should include the following elements:

- A summary of the site background, activities and staff overview (e.g., environmental information, INNS present, site use).
- A broad assessment of the INNS risks present at the site (e.g. identify the pathways and vectors/determine how INNS might be spread to and from the site).
- Appropriate and proportional biosecurity actions to address the risks identified (see mussel rope farm example).
    - Operators should be aware that their aquaculture facility/operation may have more than one pathway present – so should familiarise themselves with, and consider the actions presented in the other PAPs.
    - The biosecurity components and practical action examples within this PAP provide guidance and example actions which aquaculture operators could consider for implementation.
- Plan details (e.g., biosecurity officer/responsible staff, review period).

The following resources provide additional guidance for producing a site-specific biosecurity plan:

- Marine Biosecurity Planning (2015)
- Marine Biosecurity Planning – Guidance for Specific Operational/Construction related Activities (with template)
- INNS Management Toolkits

Plans should be regularly evaluated to review the progress, successes, failures and modifications of the actions within them. They should then be updated to reflect these outcomes by, perhaps, amending approaches, altering timescales or allocating additional resources. The plan could also be updated with current information on the distribution of any key INNS or changes to site use. Operators should consider discussing any biosecurity plan with NRW.

The use of antifouling

The application of antifouling paint, including copper-containing epoxy coatings, can help to reduce the fouling levels on equipment due to their biocidal effects, meaning that most organisms cannot survive on them. What equipment is suitable for antifouling should be considered on a case-by-case basis, but operators could consider treating supporting equipment (such as buoys, tenders, or pontoons) which is not intended to be in direct contact with farmed stock. The efficacy of the paints and coatings decreases over time, so they must be reapplied. The frequency of reapplication depends on a number of factors including the antifoulant used, the frequency of equipment usage and chemical variables in the water. Currently (depending on country) there are not strict regulations around application of antifouling paints for aquaculture. There are, however, regulations on the chemicals that can be used in antifoulants which is controlled by the Health and Safety Executive (HSE) and the Control of Pesticides Regulations (COPR). A link to the COPR approved biocidal products can be found here.

Hatcheries (Pacific oyster)

The growing of shellfish seed in hatcheries is subject to strict [shellfish health] biosecurity protocols. While these are largely focused on disease prevention, many of the biosecurity actions will also significantly reduce the risk of spreading INNS. Hatchery protocols require that any seawater used in the hatchery system is filtered, and any tanks, valves and culture equipment used in the larval and spat production cycle is cleaned with chlorine and rinsed with freshwater before the larval and spat production cycle commences. Before dispatch, spat are subject to disease testing and examination. In the UK, Pacific oyster seed is reared in seas that are free of Oyster Herpes Virus (OsHV-1) which can cause substantial mortality of oysters. As stock is typically grown-on using unfiltered or only coarsely filtered seawater, shell biofouling may still occur.

Wild seed (blue mussels)

Mussel seed used in Welsh mussel farms is commonly sourced from Caernarfon Bar, and Morecambe Bay. Adherence to the Code of Good Practice for Mussel Seed Movements is an obligatory requirement of lease agreements between Menai Strait Fishery Order Management Association (MSFOMA) and the lease holders. The code comprises two elements: i) an updated species list that describes the most up to date understanding of the status of INNS species of interest within the context of Welsh Waters, and ii) the application of the code which is broken down into the various stages in the sourcing, fishing and relaying of mussel seed, evaluating how potential hazards will be addressed at each stage of the process. In general terms, the code recommends the following steps are taken to assess the risk of introducing INNS to a cultivation site via the transfer of seed (see the code document linked in Useful resources for more details):

1. Determine if seed is from an area where there are known INNS;
2. If INNS are present, then conduct an independent survey to confirm; presence/absence on seed stock and associated materials.
3. If INNS are detected, then initiate dialogue with NRW for advice and further risk assessment;
4. If risk is unacceptable and mitigation not possible, transportation of the seed to the relay site not permitted; and
5. If INNS are not present at the seed site, INNS were not detected by the independent survey (results accepted by NRW), or risk mitigation protocols are agreed with NRW then seed can be transported to the relay site.

Additionally, introductions and transfers of marine organisms should follow the ICES Code of Practice (see Useful resources for more details).

Recommended strategic actions for authorities

Table 3 contains a list of possible strategic actions which could be taken by national authorities. Achievement of these actions support a solid statutory basis for robust management of **all marine INNS pathways in Wales, including the aquaculture pathway**. However, it is acknowledged that any statutory changes require extensive and time-consuming legislative assessments and consultation which is at odds with the urgency required for pathway and INNS management at present. It is therefore recommended that these strategic actions act as long-term goals for authorities and that priority is placed on actions that can be undertaken and achieved on shorter timescales by all stakeholders (see Recommended actions for all stakeholders).

Table 3. **Recommended strategic actions for authorities to address the introduction and spread of marine INNS via all pathways in Wales. The ID letters PS (Pathway Strategic) denote that the actions are aimed at addressing the management of pathways, differing from the ID letters SS (Species Strategic) in the Species Action Plans (SAPs) that are aimed at addressing the management of species.**

ID	Strategic action	Purpose
PS-1	**Develop a national (Welsh) position statement for key pathways in the marine environment**	The statement (and its guidance) should: • Set out the position of the Welsh Government on pathway management and lay out a national approach for addressing key marine INNS pathways. • Provide a clear objective for all marine stakeholders, supported through guidance and assistance where available. Top-down direction is a critical need for the facilitation of national, regional and local biosecurity planning. • Make it clear that improved biosecurity is the priority; however, also include goals in relation to pathway risk, surveillance and monitoring, and INNS early detection, rapid response and management. • Aim to clearly state what is expected of all stakeholders and provide realistic, measurable and agreed targets. The position should conceptually align with other GB strategies and existing regulation to ensure a consistent approach to pathway management throughout the British Isles. However, it must be grounded within a realistic Welsh focus, taking current limitations into account. To achieve the best outcomes, stakeholders should be consulted in policymaking, and policymakers should support the integration of industry expertise and experience into INNS pathways management strategies.

ID	Strategic action	Purpose
PS-2	**Review existing legislation**	A review should be undertaken of current legislation in Wales and the wider UK relating to INNS pathways to identify legislative gaps and highlight opportunities to strengthen INNS and biosecurity legislation. The review should identify primary legislation under which INNS management can be enforced (e.g., Wildlife and Countryside Act, 1981). The outcomes of this review could provide evidence, justification, and legislative support for national position statements or for introducing / amending legislation relating to pathways in Wales.
PS-3	**Introduce legislation relating to pathways in Wales**	The introduction of new legislation (or the amendment of existing legislation) in Wales relating to marine pathways can ensure a consistent and enforceable approach to biosecurity. Authorities should use evidence gathered as part of the review of existing legislation (see PS-2) as justification for new legislation. For example, the adoption of existing international resolutions (e.g., the International Maritime Organisation resolution MEPC.207(62) on biofouling) can facilitate a robust approach to pathway management in line with international standards. Legislation may not be required for, or applicable to all pathways.
PS-4	**Review and prioritise resource allocation in support of policy and legislation related to INNS**	Enforcement / enactment of existing and new policy and legislation should be considered. Resources, roles and responsibilities should be agreed and assigned to ensure that prioritised policy and legislation is being effectively enacted (e.g., provisions for enforcement officers to carry out inspections). Incentives for following legislation could be outlined in biosecurity-related award schemes or accreditations, which should be investigated, created and/or developed and endorsed by the Welsh Government or Natural Resources Wales. Penalties for offences could include fines or suspension of relevant licences as per The Invasive Alien Species Order 2019. Importantly, legislative policy needs to be clearly communicated to stakeholders.

ID	Strategic action	Purpose
PS-5	**Identify and prioritise high risk areas/locations for marine INNS introductions and impacts**	Pathway and species risk assessments are a valuable tool for identifying and prioritising high-risk locations for marine INNS and more effectively allocating resources. Data gathered from previous reports (e.g., NRW evidence report 459 and NRW evidence report "Marine Protected Areas: Features at risk from marine invasive non-native species" (pending publication) and information from the SAPs and PAPs in the biosecurity framework should be used to inform strategies for species and pathway management and surveillance. It is recognised that data used to inform pathway and species risk assessments is currently limited and further data collection is required.
PS-6	**Develop a national plan for monitoring marine INNS pathways**	A national plan should develop a standardised approach to monitoring marine pathways and implementing monitoring programs in high-risk locations (see PS-5). The procedures within this plan should be applicable and practical at local, regional and national levels with provisions included for necessary resources or support required to undertake actions. The plan could be developed in consultation with stakeholders from all levels. A cost-benefit analysis could also be undertaken to ensure that the implementation of inspections will not damage Welsh businesses.
PS-7	**Continue to develop contingency plans for key marine INNS**	Contingency plans put forward protocols for situations when a new record of an INNS is made in an area it has not been previously recorded. This can include INNS that are new to Wales and INNS that are found in some regions of Wales but not others. The protocol typically involves contacting relevant authorities and taxonomic experts for positive identification, as well as putting in place rapid actions to contain the spread of the new species. General contingency plans for marine INNS have been developed for England by the GB NNSS and a general INNS contingency plan for Wales is in draft (at time of writing, July 2025).

ID	Strategic action	Purpose
PS-8	**Improve collaboration and links between stakeholders and authorities**	Invite stakeholders to participate in existing platforms and/or forums for ongoing communication, collaboration, and knowledge exchange, such as the British Ecological Society Invasion Science Special Interest Group. Platforms like this serve as a hub where researchers, policymakers, government agencies, industry representatives, and wider stakeholders come together to share expertise, data, and resources related to INNS management. Key features should include: 1. Regular meetings and workshops; 2. Agreements for data sharing and data integration; 3. Collaborative research, leveraging the expertise and experience of the industry; 4. Capacity building; and 5. Research and monitoring priorities communicated between stakeholders. Promote the Natural Resources Wales list of high priority evidence needs and research ideas page: Natural Resources Wales / Marine and coastal evidence priorities.
PS-9	**Improve national data flow**	Data flow is fragmented, data administration slow, and existing mechanisms for priority species reports reaching authorities are inconsistent, which may delay management response. Different recording schemes have variable verification and data upload timescales as well as variable data restrictions and some records are lost in the data flow process. Authorities should work with partners including The UK Centre For Ecology & Hydrology, The Marine Biological Association, The National Biodiversity Network and Local Environmental Records Centres to ensure records arrive at the appropriate destination in a timely manner and are accessible to all. This may include continuing work with Defra on their 'improving marine NIS data access and flow efficiency' project.

Recommended actions for all stakeholders

The sections below outline seven components of biosecurity focus for the aquaculture pathway within Welsh marine areas. Stakeholder-specific guidance, including example actions for each component, is provided to support the development of tailored actions. Stakeholders are encouraged to define their own biosecurity actions, appropriately scaled and proportional to their activities, using the guidance provided.

The biosecurity components in this plan complement those outlined in the SAPs and other PAPs. They can serve as a foundation for creating a new biosecurity plan or modifying and enhancing existing procedures. For each component, high-level 'priority issues' have been identified through discussions with stakeholders. These priority issues inform the initial context for developing tailored actions.

These components are:

1. Understanding roles and legal responsibilities
2. Information and guidance on INNS and biosecurity
3. Raising awareness
4. Biosecurity processes and procedures
5. Biosecurity facilities
6. Monitoring and reporting
7. Collaborative working

1. Understanding roles and legal responsibilities

To ensure that all stakeholders are aware of the relevant and current INNS legislation and national policy that relate to aquaculture.

PRIORITY ISSUE: There is a lack of clarity within stakeholder groups (for all pathways) regarding the legal requirements for INNS management. Stakeholders require more guidance on how their activities intersect with INNS legislation, and what is required under current policy (if anything) to achieve compliance (i.e. voluntary vs. mandatory actions).

Responsible stakeholder	Guidance for Development of Actions	Example actions
Authorities	Authorities should produce a policy position or statement (see actions PS-1 to PS-4), relevant to existing or new INNS-focused legislation and regulation. This policy(s) should provide stakeholders with an improved understanding of how INNS legislation or regulation affects them. This needs to be communicated via an appropriate information cascade to include all relevant stakeholders. If legislation or regulation exists, but enforcement policy is undefined, it is recommended that stakeholders are still offered advice on this matter.	• Consult with relevant stakeholders on the implementation and feasibility of INNS focused policy. • Collaborate with the aquaculture industry to develop appropriate and achievable policy, without undue impact to Welsh blue growth and individual operators. • Ensure consistency with wider legislation and regulation (i.e. biosecurity with regards to animal health). • Establish a policy(s) for relevant regulation(s) and release a statement to provide stakeholders with a clear definition of what is expected under the legislation.

Responsible stakeholder	Guidance for Development of Actions	Example actions
National & local stakeholders	Official statements (as above) should be summarised and shared between relevant stakeholders, using plain, accessible language. Information could be included in trade association newsletters or governing body communications to relevant stakeholders (e.g., updates from national aquaculture trade associations, Fish Health Inspectorate etc.) so that all stakeholders are aware of any legal responsibilities with regards to INNS. In cases where an authority-produced statement is unavailable, national and local stakeholders are encouraged to independently review the relevant regulation and provide advice to their members as appropriate.	• Issue a press-release that summarises current national policy, highlighting the requirements for compliance with the legislation or regulation.
Aquaculture operators	It is essential to ensure a clear understanding of the Welsh Government/ NRW policy on INNS within aquaculture, as well as the associated legislation. Operators should ensure they are fully aware of what is required and expected to achieve compliance (should policy exist).	• Include an overview of the requirements under legislation and policy within toolbox talks/training for new employees. • Make employee adherence to INNS-focused policy a condition of employment. • Consult with the authority to communicate industry practice and experience and offer expert advice on the development of national legislation and policy.

2. Information and guidance on INNS and biosecurity

To ensure that information and guidance on INNS and biosecurity within Welsh marine areas are consistent, high-quality and appropriate for the aquaculture pathway.

PRIORITY ISSUE 1: Resources for INNS and biosecurity awareness are abundant but can be fragmented, making it difficult for stakeholders to navigate and identify the most relevant and appropriate information, especially without a prior understanding of biosecurity.

PRIORITY ISSUE 2: Targeted, sector-specific (i.e. pathway specific) biosecurity guidance is limited, resulting in stakeholders being unsure of what to do and when to do it.

PRIORITY ISSUE 3: Many aquaculture operators already adhere to disease-focused biosecurity obligations and perceive INNS biosecurity as an additional, disproportionate burden, unfairly directed at their industry.

Responsible stakeholder	Guidance for Development of Actions	Example actions
All stakeholders	This biosecurity component aims to address information resources on INNS for aquaculture stakeholders, ensuring that these resources are appropriate for the pathway. However, it should be noted that the provision of INNS information resources is expected to overlap significantly across all marine PAPs, SAPs and BAPs. Therefore, it is critical that authorities, as well as local and national stakeholders, take a holistic approach by integrating and co-ordinating their biosecurity activities. By doing so, they can ensure a cohesive and unified effort that builds on and enhances existing measures, maximising the effectiveness of INNS management across all marine pathways and action plans. Targeted guidance is needed to help integrate proportional, industry-beneficial and focused biosecurity actions into existing practices. Engaging the industry in consultation during policymaking, co-developing best practice advice, and fostering collaborative efforts to raise INNS awareness in Welsh marine areas are essential steps toward achieving balanced and effective biosecurity improvements. All stakeholders should ensure that resources are appropriate for aquaculture operators, tailoring specific guides to relevant operations and risk factors. Of particular relevance are the codes of good practice which already exist within the mussel and oyster farming industries, providing valuable resources for practical biosecurity measures (see Useful resources for links). However, these codes require regular review and updates to incorporate new research and information on the distribution of invasive species. Authorities could consider leading a consultation with other stakeholders on the production/review of these codes of practice.	• Download or request a copy of the NRW marine INNS identification guide (see Useful resources). Identification sheets for several marine species can also be found on the GB NNSS website. • Refine guidance to increase relevance for different aquaculture sectors. • Create an accessible central website to host biosecurity resources and information to make navigation to the most relevant information easier.

Responsible stakeholder	Guidance for Development of Actions	Example actions
Authorities	To improve INNS biosecurity in Welsh marine areas, authorities should consider creating/aligning a national-level marine INNS and biosecurity awareness raising campaign. This should provide common resources and consistent messaging for all marine stakeholders. Key highlights of the campaign could include: • A centralised location for biosecurity and INNS awareness-raising materials. While there is considerable existing material available for this action, ensuring a common repository and "endorsement" of primary materials will help stakeholders maintain consistency. • A defined list of priority INNS of concern. • Publication of INNS alerts when a population is newly established or spreading. • Clear points of contact for stakeholders seeking support and advice.	• Identification guides, such as the Welsh and English NRW ID guides (see Useful resources), should be printed and disseminated to as many relevant stakeholders as possible (e.g., local groups, aquaculture operations, points of sale). The ID guides should be kept up to date, accounting for newly introduced and horizon INNS. • Produce pathway-specific training resources which can be provided to other stakeholders. • Consult with stakeholders on the update / production / endorsement of best practice codes for INNS and biosecurity in Welsh aquaculture.
National & Local stakeholders	In the absence/interim of the action above, national stakeholders should consider the INNS information that is available. Information could include: • Key INNS to look out for • Impacts of INNS • Biosecurity best-practice Material could include self-produced resources; however, a lower effort option could review and compile the existing material already in existence (see Useful resources). Although many of these will not always be pathway specific, sources of existing, high-quality INNS biosecurity information include the GB NNSS and the International Maritime Organization (IMO) (see Useful resources for links). These resources could still be used as a basis for aquaculture relevant guidance as many of the concepts align. Where possible, information material should prioritise increasing knowledge of relevant INNS (to pathway or region) and key biosecurity messages.	• Review existing biosecurity information and tailor to the aquaculture pathway.

Responsible stakeholder	Guidance for Development of Actions	Example actions
Aquaculture operators	Operators primarily act as an end-user of the information produced by other stakeholders. However, operators can also produce information resources themselves and provide the primary expert experience for consultation with other stakeholders.	• Review the guidance received and incorporate into procedures where possible. • Consult with other stakeholders to ensure that industry practice and risk factors are considered appropriately within information resources.

3. Raising awareness

To facilitate and encourage the active sharing of information and guidance, relevant to the aquaculture pathway, among all stakeholders within Welsh marine areas.

PRIORITY ISSUE 1: Some stakeholders operating within Welsh marine areas are not aware of INNS and their impacts, or what biosecurity is. All stakeholders would benefit from more exposure to INNS awareness raising activities. All stakeholders could also facilitate the spread of information and awareness raising about INNS and biosecurity.

PRIORITY ISSUE 2: Many aquaculture operators perceive INNS biosecurity as an additional and disproportionate burden unfairly directed at their industry. The guidance available for the industry could be better targeted at specific operations and provide clearer justification. Stakeholders' buy-in may be enhanced through targeted awareness-raising efforts that recognise their existing biosecurity activities and offer appropriate support (e.g. codes of practice) for implementing proportionate and industry-relevant procedures.

Responsible stakeholder	Guidance for Development of Actions	Example actions
All stakeholders	This biosecurity component aims to increase the awareness of INNS biosecurity with aquaculture stakeholders. The materials produced under Component 2 are intended to provide the consistency and appropriateness of biosecurity information for the aquaculture pathway. However, it should be noted that raising awareness is expected to overlap significantly across all marine PAPs, SAPs and BAPs. Therefore, it is critical that all stakeholders (including authorities) integrate / coordinate their biosecurity activities. By doing so, they can ensure a cohesive and unified effort that maximises the effectiveness (and reach) of INNS information sharing. All stakeholders can have a role in raising awareness of INNS and biosecurity by promoting and disseminating existing information regarding INNS and key biosecurity messages. This could be achieved both digitally (e.g., through social media and relevant websites) and in print (e.g., in tackle shops, newsletters and magazines). There is no requirement for burdensome changes to current activities, but consideration of INNS within outwards facing communications or marketing can benefit the sustainability of all activities within Welsh marine areas.	• Engage in Invasive Species Week . Use approved or provided biosecurity resources in communications and training. A marine INNS workshop kit comprised of preserved specimens and information sheets can be borrowed from Amgueddfa Cymru (see Useful resources). • Become familiar with existing and newly developed aquaculture-focused guidance. • Share information resources with other stakeholders as widely as possible. • Provide ad hoc information/facts on INNS to staff, colleagues, members of the public, customers etc.

Responsible stakeholder	Guidance for Development of Actions	Example actions
All stakeholders continued	The Useful resources within this PAP include links to existing high-quality information sources which can be used as the basis for awareness raising. However, it is hoped that as national awareness increases, aquaculture stakeholders will expand their knowledge and activities in this area, eventually producing their own tailored resources (where they have not already done so), further amplifying awareness and engagement. Where appropriate (e.g. onshore aquaculture facilities, staging areas etc.) signage can be installed in visible (to employees and / or the public) areas. Information contained within signage can range from general actions and national guidance (e.g., the GB NNSS Check, Clean, Dry campaign), to site specific biosecurity protocols, depending on the intended audience (see Useful resources for links to signage resources). Landowner permission should be considered (if applicable or required). Equipment cleaning guidance (e.g., the GB NNSS Check, Clean, Dry campaign) should be shared by all relevant organisations and staff. For boats or submerged equipment, guidance should include information on cleaning all underwater surfaces (e.g., trestles, pontoons, buoys etc.) and removing standing/entrained water from bilges, as well as information on antifouling (e.g., the suitability of different coating types and how they should be maintained).	See actions above

Responsible stakeholder	Guidance for Development of Actions	Example actions
Authorities	Authorities should ideally be a primary source for INNS and biosecurity information in Wales. Information on available funding and resources for biosecurity should be shared with stakeholders. Messaging should ensure that stakeholders are aware of critical information, such as updates to policies (e.g. in-water cleaning rules) or species records/alerts.	• Issue regular updates/social media posts offering INNS and biosecurity advice. • Continue to engage with stakeholders, with a particular focus on improving communication links with aquaculture. • Include links or QR codes to online resources (including ID guides) with communications. Where appropriate, stock/disseminate hard copies of resources.
Aquaculture operators	Operators should ensure that staff are aware of the potential impacts of INNS, of biosecurity best-practice, inspection/monitoring methods and INNS reporting. This could be included as part of job inductions/ toolbox talks. Training and educational resources are available on the GB NNSS website (GB NNSS Training resources). Also see Component 2. However, specific/bespoke training at an operation scale should be considered.	• Use appropriate biosecurity resources to ensure staff are aware of INNS risks and trained in proportional biosecurity. • Consider communicating how improved biosecurity is beneficial to the industry and products. • Add in a link to biosecurity information on the GB NNSS website in staff updates. • Put up identification images of key INNS at the site office with a QR code to the iRecord web browser and/or to more information. Install Check Clean Dry signs at equipment stores.

4. Biosecurity processes and procedures

To improve INNS biosecurity procedures being undertaken by aquaculture operators, ensuring consistency and efficacy.

PRIORITY ISSUE: Although many operators undertake a high-level of biosecurity for the prevention of disease, INNS biosecurity receives less attention. Although there is considerable overlap between disease and INNS biosecurity, continuous improvement and inclusion of best practice in standard procedures should be considered.
Other stakeholders (such as NRW, local authorities (LAs), and county council (CC) field or operational teams) should also consider reviewing and updating their own biosecurity procedures on a regular basis.

Responsible stakeholder	Guidance for Development of Actions	Example actions
All stakeholders	This biosecurity component is primarily intended to encourage operators within Welsh marine aquaculture to enhance biosecurity procedure for INNS. However, this guidance is also highly relevant to other stakeholders interacting with the marine environment, such as (but not limited to) NRW, Local authorities, and County Council field or operational teams. At the most basic, INNS biosecurity can be achieved simply through 'Check Clean Dry' procedures (see GB NNSS information). At a high level, stakeholders are encouraged to review and update their protocols and practical procedures to ensure that operational biosecurity comprehensively addresses INNS and is consistently applied. Continuous improvement should also be a priority. These updates do not need to be onerous or burdensome, particularly as many aquaculture operators may already implement effective INNS biosecurity measures. Enhancements can leverage existing best practices, integrate example practical biosecurity actions (see **Table 5**), or adopt innovative approaches tailored by operators themselves.	• Authorities could define and provide support to national and local aquaculture stakeholders (including operators) for the implementation of improved biosecurity at aquaculture sites, or associated locations. • Consult and collaborate with the aquaculture industry to ensure best practice is encouraged and enabled. The onus should be placed on pragmatic changes to procedures which do not negatively impact Welsh blue growth or individual operators. • Regularly review emerging methods and technologies that offer INNS risk reduction. • Appoint a biosecurity manager or champion to act as a central point of contact for INNS related queries. • Consider collaborating with researchers to advance INNS management technologies.

Responsible stakeholder	Guidance for Development of Actions	Example actions
All stakeholders continued	<u>Appoint Biosecurity Managers or Champions</u> For operations of varying scales, appointing a biosecurity manager or champion can be beneficial. This individual, equipped with relevant knowledge and a defined responsibility for biosecurity, can oversee and ensure that biosecurity actions are conducted appropriately and effectively for their site, business, or organisation. <u>Research and develop INNS management measures</u> Invest and participate in the development and testing of new methods and technologies to manage INNS. For example, working with a research body / professional.	• Ensure innovative approaches and updated best practice is shared within the industry e.g. trial the use of different materials for longlines to determine which become less fouled; trial use of different antifouling against different INNS.
Aquaculture operators	Updates to existing processes and procedures do not need to be onerous or burdensome, particularly as many aquaculture operators will already implement effective disease and INNS biosecurity measures. See Table 5 for additional guidance on practical (management and control) measures for operators that could be incorporated into existing procedures. See example protocol for mussel seed movements which illustrates a possible protocol that could be undertaken to reduce the risk of spreading marine INNS as a consequence of mussel seed dredging, movement and deposition.	• Formalise INNS biosecurity procedures within existing disease-focused biosecurity plans. • Produce a stand-alone (INNS) BAP or to-do-list tracker for the individual operation and communicate with NRW for support and advice. • Incorporate additional INNS-focused procedures into routine biosecurity.

5. Biosecurity facilities

The availability of a biosecurity facility (or the supply of appropriate equipment) can help promote effective cleaning, reducing the risk of INNS being transferred to or from a location.

PRIORITY ISSUE: Washdown facilities are critical for enabling the physical cleaning of equipment, PPE, boats, and vessels. Enhancing the availability and accessibility of these facilities can substantially improve biosecurity effectiveness. To note: A review of available washdown facilities within Welsh marine areas was not included in the scope of the biosecurity framework, leaving the overall status of such facilities unknown.

Responsible stakeholder	Guidance for Development of Actions	Example actions
All stakeholders	Stakeholders who manage or own assets (e.g. aquaculture operators, marina and harbour operators, local authority managed assets where aquaculture occurs, etc.) should consider the installation of biosecurity facilities. It is acknowledged that biosecurity facilities may be multi-purpose at many locations and that facilities do not need to be overly complicated or technical (e.g. using hot water to clean rather than cold or freshwater rather than seawater). When planning installations, the following requirements, among other aspects like space and financial resources, should be considered: • The scale of the facility in proportion to the risk posed by the activity. • Infrastructure required for the collection and disposal of wastewater and waste material in a biosecure way to prevent INNS re-entering the environment (e.g., water tanks and biological waste bins). • Supply of necessary resources, like water and electricity. Guidance on the use of equipment at the facilities should be prominently displayed to ensure the correct application of the biosecurity measures.	• Install a freshwater (and if possible, a hot water) supply at aquaculture facility. • Ensure that waste is controlled in a way that minimises the risk to wider habitats. • Use existing washdown facility (following improved protocols that may be outlined in Component 4).

Responsible stakeholder	Guidance for Development of Actions	Example actions
All stakeholders continued	Additional note: It is difficult to provide a one-size-fits-all recommendation for biosecurity facilities without understanding the nuances of a particular site. The GBNNSS provides good background information and a biosecurity facility support tool, which, although currently focused on recreational pathways, offers a useful overview of facilities. Stakeholders should be reminded that biosecurity facilities do not need to be complex and could just represent a minor upgrade to existing facilities.	See actions above
Aquaculture operators	Existing disease-focused biosecurity may already address INNS biosecurity to an appropriate level. However, small changes to facilities (e.g. using hot water to clean down) can contribute considerably to the reduction of the impact and spread of INNS within Welsh marine areas.	• Review existing facilities and how they are being used. Enact small changes, following Check Clean Dry guidance and industry/biosecurity best practice to enhance the efficacy of biosecurity.

6. Monitoring and reporting

To establish a robust understanding of what INNS are present in Welsh marine areas and facilitate the early detection of introductions and spread.

To ensure that INNS sightings are reported to an appropriate platform and records are included in national databases.

To ensure that up to date species distribution data is available to facilitate rapid responses to new INNS introductions or spread events.

PRIORITY ISSUE: INNS monitoring and surveillance are insufficient in certain regions, with stakeholders often unaware of what to report or where to report sightings. Additionally, data flow is fragmented, data administration slow, and existing mechanisms for priority species reports reaching authorities are inconsistent, which may delay management response

Responsible stakeholder	Guidance for Development of Actions	Example actions
All stakeholders	This focus area aims to increase the INNS monitoring and surveillance effort by aquaculture stakeholders. Stakeholders should take an integrated approach to monitoring (see action PS-6). By doing so, they can ensure a cohesive and unified effort that builds on and enhances existing programmes, maximising the effectiveness of monitoring across all marine pathways and action plans. Stakeholders who own or manage assets (e.g. aquaculture operators, marina and harbour operators, local authority managed assets where aquaculture occurs, etc.) should consider implementing regular monitoring for INNS. Monitoring can either be undertaken and reported by stakeholders individually or could be through a collaborative effort with other stakeholders, for example those in academia. It is best to use standard procedures for monitoring high-risk INNS. Procedures may be directed from a new national approach or from existing monitoring. The best approach to monitoring for current and horizon INNS is to employ multiple methods in tandem to achieve maximum coverage of habitat and species detection.	• Promote and encourage the use of reporting / recording platforms. • Check biosecurity communications for opportunities to coordinate monitoring and collaborate. • Consider proactive monitoring through citizen science programmes. • Promote opportunities for integrated or collaborative monitoring efforts.

Responsible stakeholder	Guidance for Development of Actions	Example actions
All stakeholders continued	Some of the monitoring methods that could be employed include: • Rapid Assessment Surveys (optimal for detecting fouling organisms but not for planktonic or soft bottom habitat species); • Settlement plates/panels (panels placed in key areas for a pre-determined amount of time and checked periodically for marine growth or analysed in a lab); and • Environmental DNA (eDNA) (used to ascertain which species are present at a site using the genetic material that can be obtained from an environmental sample such as water). Stakeholders can contact NRW for guidance on monitoring INNS at their site at: invasive.non.native@naturalresourceswales.gov.uk Simple training and guidance should be provided to staff, focusing on recognising priority INNS, or being encouraged to report "unusual" growth or fouling. Confirmed or suspected INNS should be reported. This improves INNS distribution knowledge and the ability to reduce the spread. Information on how and where to report sightings should be included in all biosecurity materials and resources. NRW recommend that INNS sightings should be reported to: • iRecord online [www.irecord.org.uk/]; and • iRecord App [available on Google Play]. Potential INNS sightings can also be reported directly to NRW at: invasive.non.native@naturalresourceswales.gov.uk	See actions above

Responsible stakeholder	Guidance for Development of Actions	Example actions
All stakeholders continued	Reporters should take photos and make a note of the sighting location (ideally GPS coordinates). If possible, they should take notes about the surroundings (e.g., substrate type, other species in the area, tidal height). The reporting platform should be mentioned / linked on educational materials, at workshops and in social media engagements (see Component 2).	See actions above
Authorities	It has been recognised that the reporting of INNS sightings is not as efficient as it could be. Authorities should therefore engage with local groups, citizen science surveying groups (e.g., Seasearch and Shoresearch), Local Environmental Records Centres (LERCs)and non-governmental organisations (NGOs) (e.g., Wildlife Trusts) to set up or improve data-sharing links and ensure that sightings of high-risk species or new incursions of horizon species are passed to the relevant authority and acted on in a timely manner. This could involve establishing a list of national alert species and disseminating this list to all relevant parties (e.g., LERCs and NGOs). A critical analysis of the data flow for national INNS records should be considered, with the primary aim to improve the consistency, accuracy and timeliness of reports.	• Undertake a critical analysis of the dataflow for national INNS reports. • Ensure that priority INNS reports are flagged with relevant stakeholders (e.g. iRecord species notifications).

Responsible stakeholder	Guidance for Development of Actions	Example actions
Aquaculture operators	Individual operators will already have expert understanding of the "normal" plants and animals within their site - monitoring does not necessarily need to be a formal or costly process. Reporting unexpected fouling or growth noticed during normal operations can still provide valuable information and trigger a quick response. Where possible, relevant staff should check the aquaculture equipment, any watercraft and the shellfish for INNS as part of maintenance procedures. However, the intent is not for inspections to be operationally burdensome but to be carried out in tandem with normal procedures. It is acknowledged that not all inspection scenarios can be predicted, so some flexibility should be maintained. INNS sightings should be recorded on relevant reporting platforms or reported to NRW.	• Brief employees on the importance of INNS monitoring. • Report unusual growth or fouling to iRecord or NRW - Download the iRecord app onto work phones and encourage staff to download the app on their personal phones if they are not supplied with a work phone. Add a QR code for the iRecord web browser on relevant signage on site. • Partner with universities to provide the opportunity for students to monitor INNS presence at sites e.g. by installing settlement panels at the farm between April and September each year.

7. Collaborative working

To improve the collaboration between all stakeholders within Welsh marine areas where aquaculture is present.

To foster open communication, build trust, and align on shared goals to drive effective outcomes.

To cooperate in decision-making, share resources, and leverage the experience and knowledge of the aquaculture operators to address challenges and achieve success together.

PRIORITY ISSUE 1: Stakeholders remain uncertain about advancing biosecurity implementation without clear guidance and support from regulators and authorities. Top-down leadership is crucial, complemented by inter-stakeholder collaboration. Mechanisms for sharing information, practical advice, and bespoke guidance tailored to both national and local stakeholder needs must be developed and prioritised.

PRIORITY ISSUE 2: Opportunities for coordinated and collaborative biosecurity can be missed due to limitations in communication, leading to duplicated effort and gaps.

PRIORITY ISSUE 3: Aquaculture operators, as highly skilled experts with significant experience in practical biosecurity, represent a valuable resource. However, perceived barriers to collaboration among stakeholder groups hinder the effective utilisation of this expertise, limiting opportunities to enhance best practices, facilitate information sharing, and improve INNS reporting mechanism for the aquaculture pathway.

Responsible stakeholder	Guidance for Development of Actions	Example actions
All stakeholders	All stakeholders should work to strengthen communication and collaboration mechanisms, ensuring that practical improvements, best practices and the expert knowledge of aquaculture operators are effectively shared and considered within national or regional biosecurity implementation. Open communication channels will facilitate the flow of information from authorities to stakeholders within key sectors (i.e., those whose operations may act as pathways of introduction and spread). Open channels will also facilitate the sharing of information from stakeholders to authorities. For example, carpet sea squirt sightings in new areas.	• Engage in the biosecurity framework for Welsh marine areas in some capacity. • Consider mechanisms for collaboration and integration with other stakeholders and projects.

Responsible stakeholder	Guidance for Development of Actions	Example actions
Authorities	Authorities could consider taking a leadership/coordinating role in this process by setting clear frameworks, facilitating dialogue, and ensuring that all voices are heard. Impartial guidance is critical in driving coordinated efforts, updates to national policy, maintaining transparency, and promoting a proportional approach. Authorities should ensure close working and collaboration with relevant authorities (and other stakeholders) in England (e.g., the Environment Agency) and Europe.	• Ongoing stakeholder engagement to keep INNS at the forefront of stakeholders' activities and awareness. • Establish/task an existing working group with coordinating collaborative working. • Engage and coordinate with stakeholders to monitor progress and assess future support needs.

Action scaling: mussel rope farm example

Table 4 provides examples of how the biosecurity components and actions listed above (under "Recommended actions for stakeholders") could be scaled for implementation by a mussel rope farm operator. The actions should be tailored to the site and the relevant stakeholders for inclusion in operational procedures and/or an operational Biosecurity Action/Measures Plan.

Table 4. Example actions for a mussel rope farm.

Component	Example approach for an aquaculture site
1.Understanding roles and legal responsibilities	Include information on INNS legislation in the employee guide and a short sentence on legislation in the employee site induction.
2. Information and guidance on INNS and biosecurity	When guidance/information is received from authorities, review it to see if it is appropriate for inclusion in existing aquaculture site material. Provide feedback on guidance/information if appropriate.
3. Raising awareness	Put up identification images of key INNS at the site office. Install Check Clean Dry (or other biosecurity procedure) signs at equipment stores.
4. Biosecurity processes and procedures	Complete a biosecurity to-do-list tracker for the aquaculture operation and share it with authorities. Consider what INNS-focused procedures could be added to existing procedures. Improve PPE cleaning procedures to ensure appropriate drying time. Provide staff with equipment cleaning guidance and/or training. Appoint an operative as biosecurity manager. Trial the use of different materials for longlines to determine which become less fouled.
5. Biosecurity facilities	Install multi-use, waste-capture cleaning facilities and provide waste bins for INNS (and other debris).
6. Monitoring and reporting	Ensure that operatives report unusual growth or fouling to the site / biosecurity manager. Facilitate the reporting of suspected INNS by the site / biosecurity manager to iRecord or NRW e.g., download the iRecord app onto work phones or have a QR code for the iRecord web browser on site signage. Explore opportunities to install settlement panels at the site.
7. Collaborative working	Share information with other stakeholders, attend relevant workshops / events and provide feedback to authorities.

Practical biosecurity action examples for aquaculture operators

Table 5 below contains examples of specific biosecurity actions that could be implemented at an aquaculture site as part of routine operations and/or within the scope of Component 4. Biosecurity processes and procedures. It is recommended that aquaculture operators create a standalone BAP or to-do-list biosecurity tracker; however, this may not always be required or appropriate. For example, operators could incorporate aspects of INNS biosecurity actions into their existing protocols and procedures (an example of how actions can be scaled is given here).

These methods have been identified from available literature and guidance (see practical action references) and are based on preventing or reducing the level of biofouling (organisms, including INNS, that colonise hard surfaces) on equipment and stock.

- It is acknowledged that these actions may already be standard procedures for the sector or individual stakeholders.
- Some methods may require further research, planning and trialling before implementation.
- Any action, in the table below, that requires a Marine licence and/or Habitat Regulations Assessments, should follow the direction, advice and approval from the relevant authorities.
- There may be limitations to the application of any of these methods if being undertaken in a protected site (e.g., SSSI, SAC or MCZ).
- Appropriate disposal of INNS and treatment waste should always be considered against local rules and guidance.
- If unsure, operators can contact marinelicensing@naturalresourceswales.gov.uk or invasive.non.native@naturalresourceswales.gov.uk for further guidance and support.

For mussel seed dredging, movement and deposition, **see example protocol for mussel seed movements**.

For planning or undertaking minor work at a site, **see considerations for site maintenance and construction operations**.

Table 5. A list of practical (management and control) methods in best practice guidance and scientific literature.

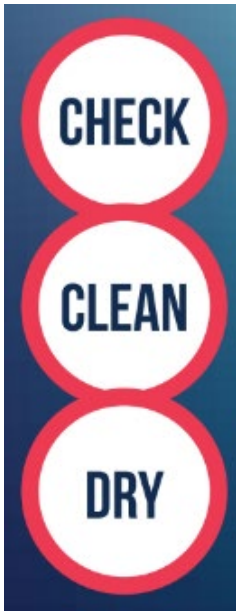
ID	Action (what)	Information
MC-AQ-1	**Remove submerged / immersed equipment from the water, and ensure they are thoroughly cleaned and dried on a regular basis.** **This should always be done before relocating any equipment to a new site/location.**	• This action aims to reduce populations of biofouling INNS at the site. • Where appropriate (and feasible), remove equipment and/or boats from the water at least once a year to remove biofouling. Avoiding in-water cleaning is important because physical disturbance can cause fouling organisms to spawn and/or break into fragments which can regrow. • Biofouling can be removed manually using pressurised water and/or a scrubbing brush. Barnacles can be crushed with a heavy object if colonising a flexible oyster bag. • Disinfectant can be used to kill any remaining organisms (see MC-AQ-2). Absorbent materials may need to be soaked. However, it is important to follow the manufacturer's instructions/regulated use relating to disinfectant use and the treatment of materials – particularly with regards to environmental release. • Collect and dispose of waste to prevent INNS from re-entering the water. • Allow equipment to dry for at least 48 hours, although depending on the material and weather conditions, drying could take longer. Some INNS can survive in damp conditions for over two weeks.

MC-AQ-2	**Treat equipment and stock that have been colonised by INNS**	• This action aims to remove/kill specific INNS.
		• Treatment methods are wide-ranging, and the suitability of methods and their effectiveness will vary depending on the INNS, the stock species, and logistical and environmental factors.
		• Treatments that have been reported as effective in some scenarios for equipment and / or stock include:
		  ○ Temporary exposure to freshwater, hypersaline water, and chemicals (e.g., bleach or acetic acid).
		  ○ Hot water (45°C is recommended) for treating equipment.
		  ○ Picking off INNS from stock by hand (if appropriate).

ID	Action (what)	Information
MC-AQ-3	**Remove unused equipment and stock from the water**	• This action aims to reduce populations of fouling INNS at the site. • Removing unused equipment and surplus/failed stock reduces the surface area on which fouling INNS can settle and grow. • Doing so can reduce the operational burden for cleaning and decrease the risk of stock mortality/loss of condition or damage to equipment. It also reduces the risk of INNS acting as a source population from which they can spread to other locations.
MC-AQ-4	**Where possible, cultivate shellfish at sites where fouling INNS are less likely to be present**	• This action aims to reduce the likelihood of INNS larvae settling on shellfish and equipment. • Determine if fouling INNS are in the cultivation area by conducting a survey of the area and/or assessing online databases such as NBN Atlas or the OneBenthic Non-native Invasive Species Tool. • Select cultivation sites where current/collected data suggests that INNS are not established or of lower risk. However, although the lack of INNS records at a site suggests a lower risk, it should not be taken as definitive 'proof' that INNS are absent. Therefore, biosecurity procedures should still be considered/implemented at an appropriate scale. • Although there are exceptions, sites that typically have fewer marine INNS present are those where the salinity is relatively low and where there is a low level of human disturbance (e.g., low level of shipping, tourism, pollution).
MC-AQ-5	**Where possible, avoid deploying equipment and out-planting shellfish during the spawning periods of fouling INNS**	• This action aims to reduce the likelihood of INNS larvae settling on shellfish and equipment. • Research the spawning times of high-impact INNS known to be present and try to avoid deploying equipment (e.g., spat collection lines), and out-planting shellfish, during these periods. • The 'Bangor Mussel Producers Limited Code of Good Practice for mussel seed movements' contains supplementary information on this – see Useful resources.

ID	Action (what)	Information
MC-AQ-6	**For mussel spat collection, use materials that maximise spat settlement but minimise fouling**	• This action aims to reduce the likelihood of INNS larvae settling on equipment. • Research and / or trial different rope materials and designs, such as “Aqualoop” and “Super Christmas Tree” ropes. Colour, substrate type, and structure can influence biofouling and spat settlement levels but is likely influenced by site-specific environmental conditions.
MC-AQ-7	**For oyster cultivation, facilitate in-situ movement of the shells during the growing phase, where appropriate**	• This action aims to reduce the likelihood of fouling organisms settling on shellfish. • Cultivate oysters in rotating containers (ortacs) that are moved by currents or in bags that can be regularly turned by hand. • Movement of oysters causes scouring of shells and periodically exposes different parts of the shell to increased desiccation and UV light which can kill fouling organisms. • Follow best practice advice and protocols, as turning bags too frequently can potentially have negative impacts on the oysters (see links to best practice guidance in Useful resources).
MC-AQ-8	**For oyster cultivation, add expanded clay aggregate or lava rock to oyster culture trays**	• This action aims to reduce the likelihood of fouling organisms settling on shellfish. • Movement of the clay aggregate / lava rock in water currents causes scouring which can kill fouling organisms. • The substrates are also “sacrificial” – biofouling organisms colonise them rather than the oyster shells.
MC-AQ-9	**Explore the use of native biological control agents (crabs, sea urchins, dog whelks)**	• This action aims to reduce the likelihood of fouling organisms growing on shellfish. • Native sea urchins or dog whelks could be added to oyster bags as they predate on biofouling organisms. ○ To reiterate, this may require further research, planning and trialling before implementation. • Ensure that the use of biological control agents has been thoroughly discussed, assessed and approved (where necessary) by the regulator. • It is important to also ensure that control agents have been sourced appropriately and will not cause impacts to non-target species, including the commercial stock.

ID	Action (what)	Information

MC-AQ-10	**Improve or adapt general operational biosecurity to include additional focus on INNS i.e. Check Clean Dry protocols. Ensuring that INNS are removed from general equipment and PPE as effectively as possible.**
	 
		Enhancing the accessibility and practicality of biosecurity procedures, such as Check Clean Dry is a simple, but highly effective way of reducing the operational risk of INNS spreading to/from/within aquaculture sites. Although primarily a local stakeholder (operator) responsibility, anyone visiting an aquaculture site should be mindful of their own biosecurity. Check Clean Dry (see Component 4).
		• Check gear for mud, aquatic animals or plant material. Remove anything you find and leave it at the site.
		• Clean everything thoroughly as soon as you can, paying attention to nets, PPE, and areas that are damp and hard to access. Use hot water if possible.
		• Dry everything for as long as possible before using elsewhere. Some INNS can survive for two weeks in damp conditions.
		By tailoring Check Clean Dry protocols to the specific equipment, processes, and challenges of aquaculture, these measures can significantly reduce the risk of spreading INNS and enhance the biosecurity of sites. The following approaches can help.
		Accessible and site-specific washdown facilities (see Component 5)
		• On-site washdown: install dedicated cleaning stations at aquaculture sites for equipment, vehicles, and personnel. These can include:
		  ○ High-pressure washing units for cleaning nets, cages, and boats.
		  ○ Disinfectant baths or sprays for smaller tools and protective gear (e.g., boots and gloves).
		  ○ Designated drying areas to ensure equipment is fully dried before reuse.
		• Proximity to active areas: place facilities near high-use/high-risk areas, such as entry points, gear storage, etc.
		• Portable units for remote/infrastructure lacking sites: portable or mobile cleaning equipment for aquaculture operations in remote or ensuring no site or staff member is left without access to proper cleaning tools.
		  ○ Personal kits: provide aquaculture staff with personal cleaning kits that include items such as disinfectant sprays, brushes for cleaning small tools, and microfiber cloths for drying surfaces.
		• Consider equipment-specific solutions: design cleaning protocols and tools for commonly used aquaculture equipment, such as: nets and cage panels, pumps and hoses used for water intake or drainage, mooring and anchoring systems.

Example protocol for mussel seed movements

The guidance outlined below is intended to illustrate a possible protocol that could be undertaken to reduce the risk of spreading marine INNS as a consequence of mussel seed dredging, movement and deposition. It is understood that these may not be feasible or appropriate in every situation. Natural Resources Wales provides tailored advice on a case-by-case basis, customised to the specific activity, location, and resources available to the operator.

- Marine INNS, e.g., the American slipper limpet (*Crepidula fornicata*) can be found in multiple areas along the Welsh coastline. Therefore there is potential for slipper limpet to be present in unknown areas, either as newly settled individuals on the mussel seed, or as newly settled or larger individuals on the substrate or macrofauna on the mussel seed bed.
- It is unlikely to be possible to identify the presence of any newly settled slipper limpet on the mussel seed prior to deposition, but it may be possible to identify the presence of any larger slipper limpet on animals or substrate that is dredged up prior to deposition.
- There are options to mitigate the risk of slipper limpet being introduced/spread through the mussel seed dredging, movement and deposition. These are, in order of operations:

1. **Pre-dredge** – Visually assess the mussel seed bed at the designated site prior to dredging using underwater cameras to check for any obvious signs of slipper limpet being present on the mussel seed, substrate, or other animals. If slipper limpets are identified, do not dredge.
2. **During dredge** – Conduct single dredge runs over newly settled mussel seed to minimise the risk of picking up underlying substrate which may have slipper limpets present.
3. **Post-dredge, onboard vessel** – Visually assess the mussel seed and other material as it arrives on the boat on the inspection belt. Set the inspection belt to the lowest speed possible to allow for thorough inspection. If slipper limpets are identified, remove and dispose of them appropriately. A designated inspector could visit the boat to check the feasibility of this.
4. **Post-dredge, onboard vessel** – Set the spacing and speed of the variable speed shaker/washing system of the inspection belt to allow mussels to pass through but retain any larger individuals on the belt. Remove and dispose of larger animals or substrate that may have slipper limpets on them appropriately.
5. **Post-dredge, onboard vessel** – Inspect mussel seed as it arrives in the holds to remove any other remaining larger animals or substrate that may have slipper limpets on them and dispose of them appropriately.
6. **Post-dredge, post-deposition** – Deposit mussel seed in a high intertidal area (location to be agreed) where it can be accessed on foot for inspection. A designated inspector to regularly inspect over the winter and prior to spawning season (March onwards) to check for the presence of slipper limpets and report back to the relevant authorities. The authorities to also conduct inspections over the winter. If slipper limpets are

identified in surveys/inspections across the bed, remove all deposited material and dispose of slipper limpets appropriately. Continue inspections until the seed is to be moved to lower intertidal areas to grow. If slipper limpets are identified in surveys/inspections, remove all deposited material and dispose of slipper limpets appropriately. A designated inspector to provide a report on the method for a recent slipper limpet survey.

- **Development of a protocol** for mussel seed movements from designated sites incorporating the above actions would minimise the risk of introducing/spreading slipper limpets to nearby areas.
- **Additional Measures**: There may also be merit in taking water samples or plankton trawls to identify the presence of slipper limpet larvae in the water column in the area to confirm or rule out their potential presence in different parts of the region. This would help assess the risk of mussel seed movement around the area. The designated inspector to discuss this with a local university.

Considerations for site maintenance and construction operations

The following guidance is for consideration by site owners, site operatives and other relevant actors when planning or undertaking minor work at a site.

The Welsh National Marine Plan 2019 contains a cross-cutting policy specifically relating to INNS. Under Policy ENV_03, proposals for inshore and offshore developments in Welsh marine areas should assess the likely risk of introducing or spreading INNS and put in place reasonable biosecurity measures where necessary to reduce or stop their introduction or spread.

Some general operational activities might risk spreading INNS. These include minor works, repairs, maintenance and construction that would not necessarily need a marine licence so there may not be an assessment or an understanding of the risk that the activity might pose in spreading INNS.

Activities, which may fall under Band 1 licencing eligibility, are listed below. It is important to note that the NRW Permitting Service may still be required to consider the appropriateness of the activity before determining the licence application (see Natural Resources Wales website for more information).

- Repairing, replacing or reasonably improving parts or ancillary equipment attached to existing structures (e.g., bolts, flaps, valves, cathodic protection, access covers, grills, joints, decking on a pier or pontoon, health and safety equipment etc.).
- Installing scaffolding/access towers to facilitate the maintenance of existing structures.
- Replacing render or concrete, including resurfacing slipways (excludes work on coast protection structures, such as sea walls).
- Removal of marine growth and/or guano from any structure (other than from vessels).
- Installing ladders at any building or structure.
- Dropping or removing posts for marking channels, shallow water areas, outfalls and groynes.
- Dropping or removing marker buoys.
- Removing discrete pieces of debris associated with construction, demolition, damage or disrepair of a building / structure (using a vehicle or vessel).
- Removing litter (using a vehicle or vessel).

Biosecurity is not necessarily considered when undertaking each of the above activities and guidance on how to address the risks of this minor pathway is not as well developed (or specialised) as it is for other pathways in the marine environment (see Useful resources). As such, it is important to set out general procedures for operatives to follow to reduce the risks of introducing or spreading INNS into, around or out of their site. However, the intention is not to add onerous risk assessments and checks to everyday operations but to ask operatives to be mindful of potential risks and take basic steps to minimise them.

Activity: Cleaning, maintenance or removal of structures / items in the water

Suggested Biosecurity Actions

- Visually inspect them before disturbing them.
- If they have fouling on them, try to minimise the risk of releasing the species into the water:
    - Bring the structure out of the water before carrying out the work and retain the detritus that comes off the item (collect it and dispose of it on land).

Activity: Bringing new infrastructure / equipment and material on site

Suggested Biosecurity Actions

- Ensure it is fully clean and dry before it is deployed.
- If unclean when it arrives, take to a suitable location for cleaning, this should be a contained area of hard-standing with appropriate drainage. Wastewater and waste material should be collected and disposed of in a biosecure way to prevent INNS (including larvae, fragments, etc.) re-entering the environment (e.g. water tanks and biological waste bins).If possible, check the source of the item(s) and understand what INNS are present at that site (this can be done by searching the location on the NBN Atlas or on iRecord which are both open-access and free to use).

Activity: General operational good practice for infrastructure

Suggested Biosecurity Actions

- Where practical, remove man-made structures from the water when they are not in use.
- Temporarily move items out of the preferred growth zone. For example, dropping the mooring chain to the seabed when not in use will smother fouling (in muddy sediments) or prevent new growth.
- Air dry what you can, when you can. Identify opportunities to dry out equipment or infrastructure as often as possible, e.g., drying room/area for kit, PPE etc.
- Expose to fresh water. Make the most of any natural flows of freshwater into your site. Expose INNS to fresh water through immersion or wash down.
- Photograph fouling on buoys / pontoons when they are taken out for maintenance to keep a record of growth and inspect for any new INNS.

Useful resources

- Assessing the impact of key Marine Invasive Non-Native Species on Welsh MPA habitat features, fisheries and aquaculture

- **Bangor Mussel Producers Limited Code of Good Practice for mussel seed movements:**
  2019 version
  2008 version

- ICES Code of Practice on the Introductions and Transfers of Marine Organisms 2005

- IOC-UNESCO and GEF-UNDP-IMO GloFouling Partnerships report on "Biofouling Prevention and Management in the Marine Aquaculture Industry"

- European Native Oyster Habitat Restoration Handbook (2020), Chapter 4: Biosecurity in native oyster restoration (zu Ermgassen *et al.*)

- Report for the Shellfish Association of Great Britain: The Pacific oyster (*Crassostrea gigas*) in the UK (p. 107 – "proposed management plan for an oyster farm in Wales")

- Report for Sea Fish Industry Authority: Development of a Pacific oyster aquaculture protocol for the UK – technical report

- Shellfish Centre Canolfan Pysgod Cregyn

- **GB Non Native Species Secretariat (NNSS) resources:**
  - Check Clean Dry
  - Marine Biosecurity
  - INNS Management Toolkits
  - Information Portal

- Health and Safety Executive list of approved biocides

- Welsh marine INNS priority list

- Natural Resources Wales marine INNS identification guide in Welsh

- Natural Resources Wales marine INNS identification guide in English

- Marine Biological Association INNS identification guide

- **Welsh marine INNS workshop kit:** May be borrowed by anyone who is running a supervised workshop for adults. It includes specimens, images, distribution maps and species information. For more information or to borrow the kit, contact: anna.holmes@museumwales.ac.uk.

- **Links to other national Pathway Action Plans (PAPs) and Species Action Plans (SAPs):**

  Links to the action plans listed below can be found on the Wild Seas Wales website.

  - American slipper limpet, *Crepidula fornicata* SAP
  - Chinese mitten crab, *Eriocheir sinensis* SAP
  - Carpet sea squirt, *Didemnum vexillum* SAP
  - Trumpet tubeworm, *Ficopomatus enigmaticus* SAP
  - American oyster drill, *Urosalpinx cinerea*, & Japanese oyster drill, *Ocinebrellus inornatus* SAP
  - Recreational Boating (small boats) PAP
  - Recreational Boating (large boats) PAP
  - Recreational Activities PAP
  - Commercial Shipping PAP
  - Shore-based Fishing PAP
  - Boat-based Fishing PAP

Table 6 below, from a 2006 paper, outlines a ranking system for hull fouling which can be used for reference when undertaking inspections of vessels. Similar hull fouling ranking has been employed in other biosecurity inspection programs.

Rank	Description	Visual estimate of biofouling cover
0	No visible fouling. Hull entirel clean, no biofilm* on visible submerged parts of the hull.	Nil
1	Slime fouling only. Submerged hull areas partially or entirely covered in biofilm, but absence of any plants or animals.	Nil
2	Light fouling. Hull covered in biofilm and 1-2 very small patches of one type of plant or animal.	1-5% of visible submerged surfaces
3	Considerable fouling. Presence of biofilm, and fouling still patchy, but clearly visible and comprised of either one or more types of plant and/or animal.	6-15% of visible submerged surfaces
4	Extensive fouling. Presence of biofilm and abundant fouling assemblages consisting of more than one type of plant or animal.	16-40% of visible submerged surfaces.
5	Very heavy fouling. Many different types of plant and/or animal covering most of visible hull surfaces.	41-100% of visible submerged surface

Table 6: Hull fouling ranking from Ashton, G.V., Boos, K., Shucksmith, R. and Cook, E.J., 2006. Risk assessment of hull fouling as a vector for marine non-natives in Scotland. Aquatic Invasions, 1(4), pp.214-218. *biofilm: thin layer of bacteria, microalgae, detritus and other particulates.

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