

Invasive Non-native Species Action Plan for Wales:

Carpet sea squirt (*Didemnum vexillum*)



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APEM Ltd. And Natural Resources Wales

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Crynodeb

- Mae [rhywogaethau estron goresgynol](#) yn blanhigion, anifeiliaid neu bathogenau nad ydynt i'w cael yn naturiol mewn ardal ond sydd wedi cael eu symud yno, fel arfer gan weithgareddau dynol (naill ai'n ddamweiniol neu'n fwriadol) ac maen nhw'n achosi effeithiau amgylcheddol, cymdeithasol neu economaidd sylweddol. Rhai o effeithiau rhywogaethau estron goresgynol yw eu bod yn cystadlu'n llwyddiannus â rhywogaethau brodorol am fwyd a gofod, eu bod yn newid cynefinoedd, lledaenu clefydau ac achosi costau uniongyrchol ac anuniongyrchol i economïau lleol a chenedlaethol.
- Mae symudiad (h.y. cyflwyno a lledaenu) rhywogaethau estron goresgynol yn cael ei hwyluso gan drywyddau a gweithgareddau dynol o'r enw "[Llwybrau](#)", er enghraifft, llongau, cychod hamdden a dyframaethu.
- Er mai'r ffordd sy'n cael ei mabwysiadu fel arfer i leihau effaith rhywogaethau estron goresgynol yw ymdrechu i atal cyflwyniad a lledaeniad ar lefel y llwybr, mae sawl rhywogaeth estron oresgynol wedi cael ei blaenoriaethu gan Cyfoeth Naturiol Cymru.
- Nod cyffredinol y Cynllun Gweithredu Rhywogaeth hwn yw lleihau'r risg o gyflwyno a lledaenu'r chwistrell fôr oresgynol *Didemnum vexillum*, drwy gyflwyno camau gweithredu y gellir eu rhoi ar waith ar lefelau cenedlaethol (Cymru), rhanbarthol a lleol.
- Mae'r Cynllun Gweithredu Rhywogaeth hwn yn rhoi trosolwg o *Didemnum vexillum*, ei [ymddygiad a'i gylch bywyd](#), [llwybrau lledaenu](#) ac [effeithiau](#), yn ogystal â chymau y gellid eu rhoi ar waith i [fynd i'r afael â lledaeniad y rhywogaeth hon](#).
- Ymysg effeithiau negyddol y math hwn o chwistrell fôr mae: disodli rhywogaethau brodorol; tyfu'n drwch dros arwynebau (gan gynnwys rhywogaethau byw); a llygru seilwaith dyframaethu, cyrff llongau, offer, ac ati. Mae'r problemau hyn yn achosi gwaith rheoli ac atgyweirio costus, yn ogystal â difrod uniongyrchol i'r amgylchedd morol.
- Mae'r camau gweithredu a amlinellir yn y Cynllun Gweithredu Strategol hwn yn darparu cyfres o gamau gweithredu i randdeiliaid amgylchedd morol Cymru y gellid eu rhoi ar waith lle mae *Didemnum vexillum* wedi'i nodi fel blaenoriaeth neu risg uchel.
- Rhanddeiliaid yw'r rhai sy'n defnyddio, yn elwa o, neu sy'n gyfrifol am (e.e. rheoli, amddiffyn neu reoleiddio) yr amgylchedd morol. Yma, mae hyn yn cynnwys awdurdodau (h.y. cyrff sydd â phwerau i gyflwyno, diwygio a gorfodi rheoliadau, deddfwriaeth a pholisi), cyrff statudol, rhanddeiliaid anllywodraethol cenedlaethol (e.e. cyrff llywodraethu hamdden, cyrff anllywodraethol, cymdeithasau ac ymddiriedolaethau), gweithrediadau masnachol, awdurdodau porthladdoedd a harbwrfeistri, defnyddwyr hamdden ac unigolion. Gweler [Rhanddeiliaid allweddol](#) am enghreifftiau pellach.
- Mae'r Cynllun Gweithredu Rhywogaeth yn amlinellu saith cydran o ffocws bioddiogelwch i'w gwneud gan randdeiliaid sy'n mynd i'r afael â *Didemnum vexillum* o fewn ardaloedd morol Cymru.
 1. [Deall rolau a chyfrifoldebau cyfreithiol.](#)
 2. [Gwybodaeth ac arweiniad ar *Didemnum vexillum*](#)
 3. [Codi ymwybyddiaeth](#)
 4. [Prosesau a gweithdrefnau bioddiogelwch](#)
 5. [Rheoli rhywogaethau](#)

6. [Gwyliadwriaeth ac adrodd](#)

7. [Gweithio ar y cyd](#)

- Bwriedir i'r cynllun hwn gael ei ddefnyddio i gefnogi'r [Cynlluniau Gweithredu Llwybrau \(PAPs\)](#) a'r [Cynlluniau Gweithredu Boddigolwch \(BAPs\)](#) cysylltiedig.

Summary

- [Invasive non-native species](#) (INNS) are plants, animals or pathogens that do not naturally occur in an area but have been moved there, usually 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. introduction and spread) of INNS is facilitated by human mediated routes and activities called “[Pathways](#)”, for example shipping, recreational boating and aquaculture.
- Although reducing the impact of INNS is commonly approached through efforts to prevent introduction and spread at the pathway level, there are several INNS that have been prioritised by National Resource Wales.
- The overall aim of this Species Action Plan is to reduce the risk of the introduction and spread of the carpet sea squirt, *Didemnum vexillum*, by putting forward actions that can be applied at national (Welsh), regional and local levels.
- This SAP provides an overview of the invasive carpet sea squirt, its [behaviour and life cycle](#), [pathways of spread](#) and [impacts](#), as well as actions that could be implemented to [address the spread of this species](#).
- The negative impacts of the carpet sea squirt include outcompeting native species, smothering surfaces (including living species) and fouling of aquaculture infrastructure, vessel hulls, equipment, etc. These issues lead to costly management and repairs, as well as direct harm to the natural marine environment.
- The actions outlined within this SAP provide stakeholders of the Welsh marine environment a series of actions that could be implemented where the carpet sea squirt has been identified as a priority or high risk.
- Stakeholders are those that use, benefit from or are responsible for (e.g. managing, protecting or regulating) the marine environment. Here, this includes authorities (i.e. bodies with powers to introduce, amend and enforce regulations, legislation and policy), statutory bodies, national non-governmental stakeholders (e.g., recreational governing bodies, NGOs, associations and trusts), commercial operations, port authorities and harbourmasters, recreational users and individuals. See [Key stakeholders](#) for further examples.
- The SAP outlines seven components of biosecurity focus to be undertaken by stakeholders that address the carpet sea squirt within Welsh marine areas.
 1. [Understanding roles and legal responsibilities](#)
 2. [Information and guidance on the carpet sea squirt](#)
 3. [Raising awareness](#)
 4. [Biosecurity processes and procedures](#)
 5. [Species management](#)
 6. [Monitoring and reporting](#)
 7. [Collaborative working](#)
- This plan is intended to be used in support of the associated [Pathway Action Plans \(PAPs\)](#) and [Biosecurity Action Plans \(BAPs\)](#).

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 Species Action Plan provides information and guidance to support stakeholders with their biosecurity efforts in Welsh marine areas, where the carpet sea squirt is considered a priority threat.

It is acknowledged that no single activity is solely responsible for the spread of INNS, and no single species should be targeted at the expense of wider holistic efforts. All users of the marine environment are encouraged to take the time to understand more about the carpet sea squirt 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 paper from Eschen](#)).

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. 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 (referred to as “spread” in this document):
 - a. Facilitating the short-range dispersal (i.e. spread from place of introduction to wider area) 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 trans-oceanic 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 Welsh Pathway Action Plans. Links can be found on the [Wild Seas Wales website](#).

Vectors are the specific, discrete parts of a pathway that facilitate the movement of INNS from one location to another. For example, 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.

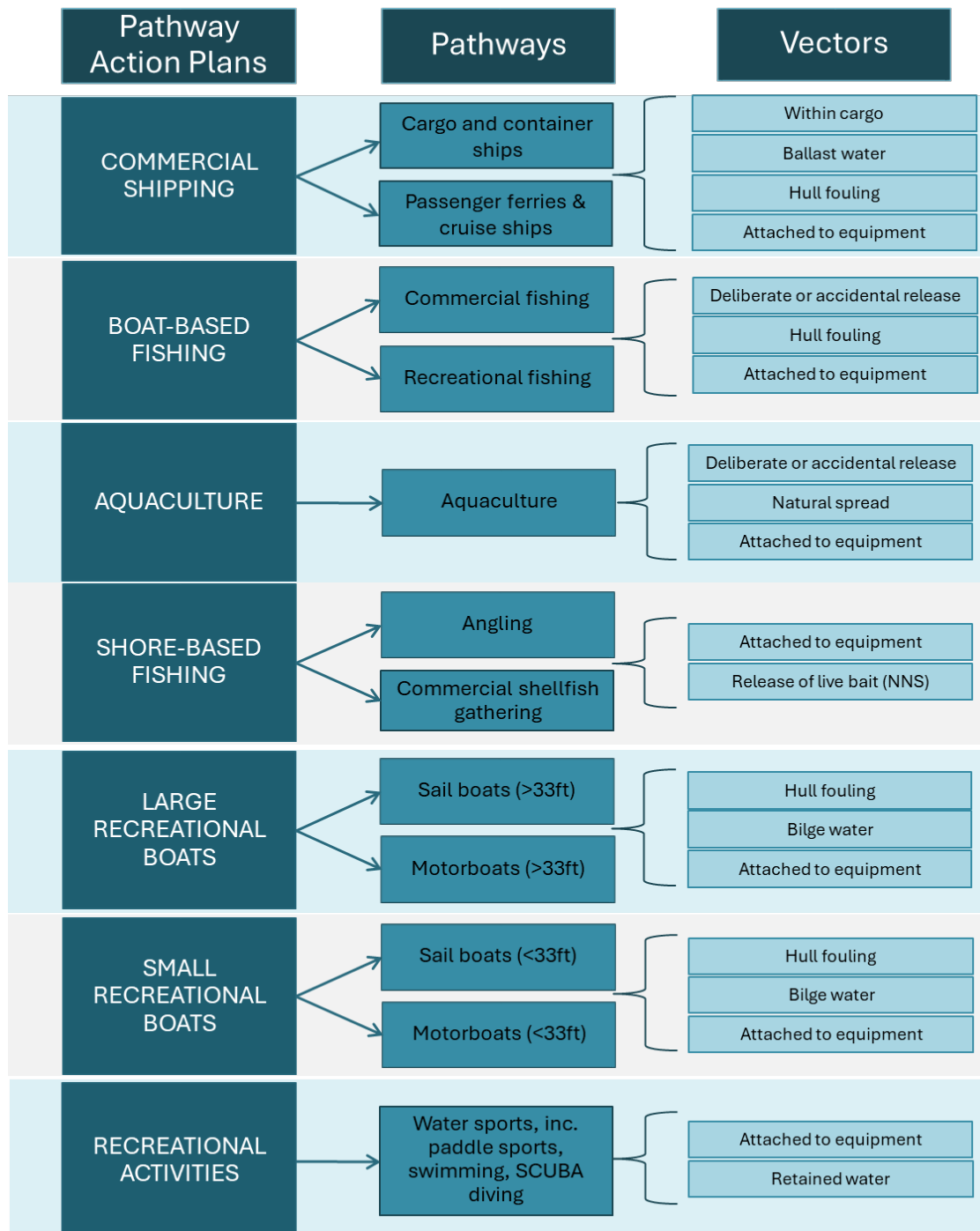


Figure 1. An overview of the Pathway Action Plans that have been developed for Wales, and the vectors associated with the pathways. Note that the list of vectors is not exhaustive.

What is biosecurity?

Biosecurity measures are actions, procedures and behaviours put in place to reduce the risk of INNS introduction and spread 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.

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

This Species 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 1 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. BAPs can be scaled as appropriate but there are no barriers to producing a BAP for a whole region (i.e. as has been done for the Pembrokeshire Marine, Cardigan Bay, Menai Straits and Carmarthen Bay 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.

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.

This framework has not been created with punitive or intentionally burdensome measures, and we encourage aquaculture operators to consider the benefits of improved biosecurity to both the sustainability and profitability of the industry.

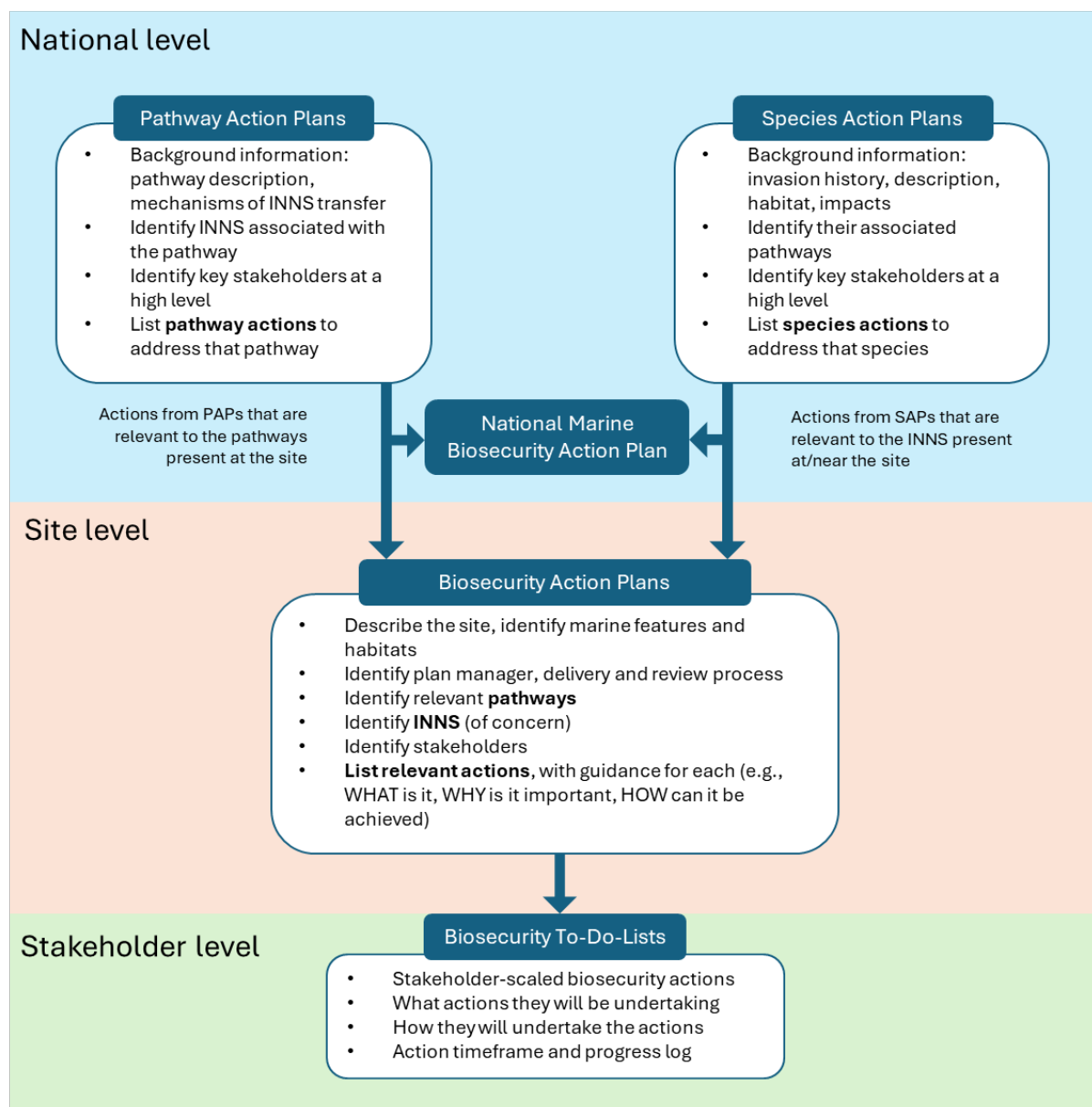


Figure 2. A flowchart showing the relationships between the Pathway Action Plans, Species Action Plans and the Biosecurity Action Plans created for the Natural Resources Wales Biosecurity Planning Project with APEM Ltd.

Scope, aims and objectives

Scope

This Species Action Plan (SAP) is intended to be applicable across all Welsh marine areas, presenting actions that can be undertaken by relevant parties (outlined below) to manage the introduction and / or spread of the carpet sea squirt, *Didemnum vexillum* (referred to as the carpet sea squirt from here onwards). The actions outlined in this document are intended to complement those within the PAPs (available on the [Wild Seas Wales website](#)) in order to be more readily incorporated into BAPs, as described in the [framework](#) above. As such, there will be some overlap between the actions recommended in this SAP and the actions recommended in the PAPs. This document is aimed at:

- Individuals, organisations or groups undertaking activities in the marine environment.
- Regulators, governmental organisations and local authorities planning the implementation of policy, legislation or regulations.

The actions and guidance outlined in this document encompass several dimensions of INNS management for the carpet sea squirt, 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; and
- National policy and regulatory frameworks

Aim

The overall aim of this SAP is to reduce the risk of the introduction and spread of the carpet sea squirt by putting forward actions that can be applied at national (Welsh), regional and local levels. The goal is to use existing INNS and carpet sea squirt specific awareness raising communications and biosecurity 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 species across Wales.

Objectives:

- Increase public awareness of the carpet sea squirt and the risks it poses.
- Put forward recommendations for actions that aim to reduce the further introduction and spread of the carpet sea squirt into and around Wales and improve surveillance and reporting of new individuals.
- Outline possible control methods for the carpet sea squirt that have previously been employed elsewhere.

The carpet sea squirt: Background

Table 1. A summary of the carpet sea squirt (*Didemnum vexillum*) background information.

Attribute	Details
Native range	Northwestern Pacific
Appearance	Firm, leathery “carpet”. Pale/dull orange, cream or off-white. Veined/marbled.
Substrate	Natural and artificial hard surfaces. Some stable soft substrates. Other organisms.
Depth	Intertidal zone to 80m depth.
Temperature tolerance	0-28°C. Optimum growth 14-18°C. Colony die back below 5°C.
Salinity tolerance	20psu to 45psu. Optimum 26psu to 30psu
Feeding method	Filter feeder
Reproduction/Propagation	Sexual (self-fertilisation and cross-fertilisation) and asexual (budding). Colonies can also propagate through fragmentation.
Predators	Predation by some gastropods. Predation by other marine organisms, like fish, starfish and urchins may also be likely.
Pathways and vectors	Fouling (on vessels and infrastructure), hitchhiking (equipment and aquaculture stock), ballast and bilge water, marine litter and natural spread.
Impacts	Competition and habitat alteration, overgrowth and smothering and socio-economic.

Where did it come from?

The carpet sea squirt, *Didemnum vexillum*, is native to the Northwestern Pacific (likely Japan) but has become almost globally widespread.

Non-native range

The carpet sea squirt was first recorded in Europe on the Dutch coastline in 1991 where it remained relatively rare until the population rapidly expanded in 1996. Soon afterwards, in 1998, the carpet sea squirt was found in France. It was first officially recorded in the UK in 2008 in Holyhead Marina (see the [2009 Griffiths paper](#)). However, it is possible that the species had been present in the UK for some time prior to this but went undetected. The carpet sea squirt has now been recorded along the south and east coasts of England (from Devon to Essex), on the north-western and south-western coasts of Wales, on the West coast of Scotland and on the east and west coasts of Ireland.

What does it look like?

The carpet sea squirt is a colonial animal comprising multiple individuals, called zooids. Each zooid is approximately 1mm in length, and less than 1mm in width, forming a sac-like shape. The zooids lie next to one-another, forming a firm, leathery expanse. It is typically a pale or dull orange, cream or off-white colour, 2mm to 5mm thick, and sometimes metres wide. The carpet has many pores (one for each zooid) that close when disturbed or taken out of water, forming tiny whiteish spots. These spots, combined with dark-coloured channels which separate clusters of 10 or more zooids, give the carpet a veined or marbled appearance. Additionally, there are openings (a few mm across) in the carpet that are non-uniformly spread.

The carpet sea squirt sometimes grows on itself, creating a variety of folds in the carpet, and can form hanging lobes that reach 1m in length. The carpet sea squirt looks similar to other species within the same family (Didemnidae) and some species of sponges. However, a feature that distinguishes the carpet sea squirt from other colonial sea squirts is the lack of black and/or brown markings on its surface. Due to the visual similarities between the carpet sea squirt and other sea squirt species, it can be challenging to confirm identification. It is therefore recommended that a specialist confirms identification with a microscope. Observations of the larvae that are brooded within the carpet are useful for identification.

Identification guides have been developed by several organisations and links can be found linked in [Useful Resources](#).

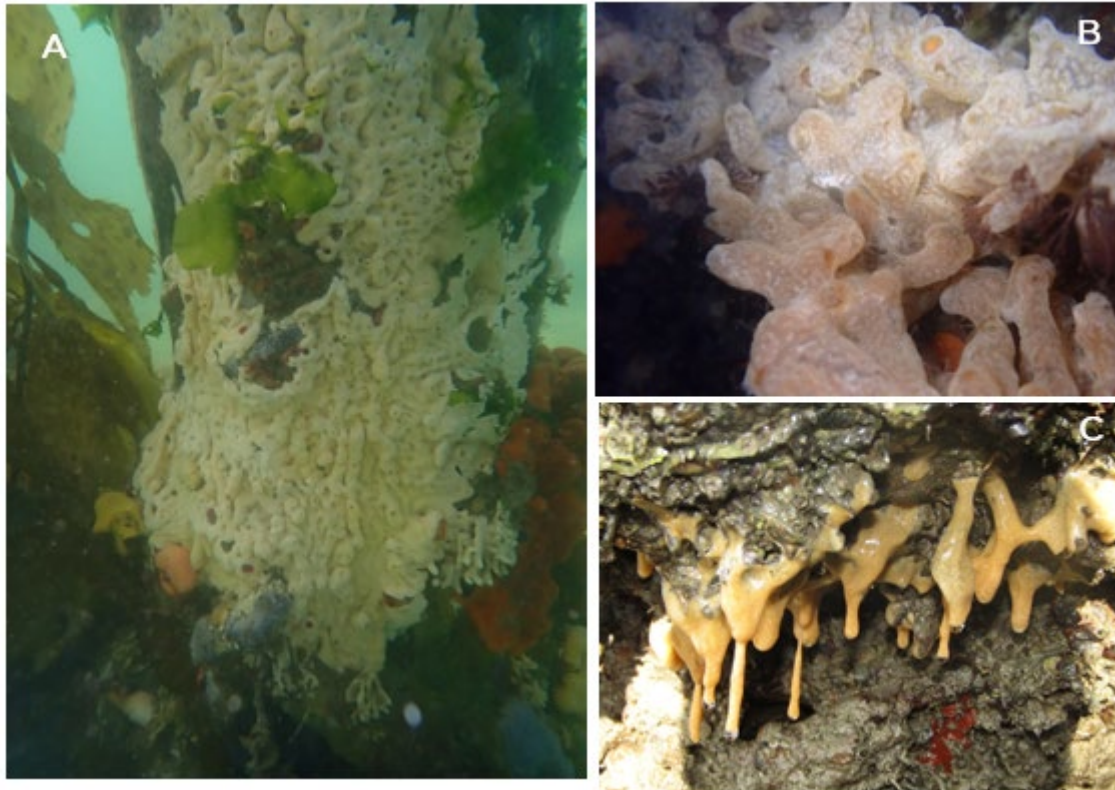


Figure 3. A) Carpet sea squirt growing on a hard surface. © Julien Renoult, CC BY, accessed via iNaturalist. B) Close-up of the carpet sea squirt. © Cricket Raspet, CC BY, accessed via iNaturalist. C) The carpet sea squirt hanging down from a rock. © Saryu Mae, CC BY, accessed via iNaturalist.

What habitat does it live in?

The carpet sea squirt can grow over a variety of hard surfaces and some stable soft surfaces. Colonies can carpet a wide variety of hard substrates such as gravel, cobble, and rocks, and grow on various organisms such as oysters, sponges, hydroids, tunicates, and algae. The carpet sea squirt can also cover artificial structures including boats, pontoons and aquacultural equipment. Colonies can be found in both polluted and relatively clean waters. The carpet sea squirt is generally found in tidal estuaries, harbours and lagoons, on both horizontal and vertical surfaces. Tolerant of a wide range of environmental conditions, the carpet sea squirt colonises depths ranging from the intertidal zone (i.e., shallow waters that may be exposed at low tide) to 80m deep. It is usually found in low energy environments (i.e., where there is little water movement), but has also been recorded in areas that experience a high degree of wave action.

The carpet sea squirt grows particularly quickly in shallow (1m deep) waters and where there is typical seawater salinity (26 to 30psu (practical salinity units)), although it can tolerate salinities ranging from approximately 20 to 45psu. If salinities are less than 20psu, colonies start to die-off. Observed in areas with water temperatures ranging from 0-28°C, the optimum

temperature range for growth is between 14 and 18°C. Die back of colonies often occurs at temperatures below 5°C.

Behaviour and life cycle

The carpet sea squirt is a filter feeder, extracting food, in the form of tiny organic particles such as plankton, from the water column. Growth rates, and therefore abundance, are seasonal, with colonies growing more slowly and often dying in the coldest winter months. In optimal conditions (see above), the growth of small colony fragments can be rapid, with 6 to 11-fold growth possible in 15 days.

Each individual zooid of the carpet sea squirt colony is a hermaphrodite, meaning it possess both female and male sex organs, and does not require another individual to reproduce. The carpet sea squirt is able to reproduce in multiple ways which has facilitated its spread. Firstly, the carpet sea squirt can produce larvae via sexual reproduction resulting from self-fertilisation, or fertilisation with another individual (cross-fertilisation). The larvae are released into the water column where they remain for only a few hours before they settle, so larval dispersal is usually limited to the local vicinity. However, larval dispersal greater than 250 m, or sometimes 1 km, is theoretically possible via ocean currents. The release of larvae occurs when water temperatures are between 14 and 20°C. The carpet sea squirt can also reproduce via asexual reproduction, whereby new zooids bud from existing ones and so are genetically identical – this is how the colonies (carpets) form. Colony growth by asexual budding is initiated by water temperatures greater than 8-12°C. Finally, fragments of the colony can break off and are carried by currents to a new location where they settle and grow. This is why it is important to avoid fragmenting the colonies when carrying out hull cleaning or other similar actions.

Genetic strains of carpet sea squirt

It appears there are different genetic strains of the carpet sea squirt in different locations in the UK and between marina and aquaculture sites. Genetic analysis carried out by Aberystwyth University in 2024 revealed that the carpet sea squirt found in Milford Haven is genetically more similar to that found in Kent than in Holyhead or Dublin. In Holyhead, the carpet sea squirt predominately grows on artificial structures and seems to be restricted to the marina. In Milford Haven it has been found growing on natural substrate such as stones, gravel and seaweeds.

The substrate preference of the carpet sea squirt may have implications for its rate and ease of spread, and therefore the management strategies considered. Information is still being sought about how this adaptable species behaves in Milford Haven.

Does it have any predators?

Predation on the carpet sea squirt can be limited as it has sharp external structures (called spicules) and its tunic (the name for the outer covering of the zooid) is acidic. However, some gastropods are known to predate on the carpet sea squirt. The common periwinkle (*Littorina littorea*) has been observed grazing on deteriorating colonies in Massachusetts, USA. The

Arctic cowrie (*Trivia arctica*) and a sea snail (*Lamellaria* sp.) were also reported to be feeding on the carpet sea squirt in the Netherlands. Predation by other marine organisms, like fish, starfish and urchins may also be likely.

What are its pathways and vectors?

Pathways are the mechanisms and routes by which INNS are moved from one geographic location to another, and vectors are the specific, discrete parts within a pathway that facilitate the movement of INNS from one location to another. The pathways and vectors for the carpet sea squirt are described below.

Fouling on hulls and infrastructure

The carpet sea squirt has been reported on propeller shafts, rudders and hulls, and can grow on other organisms fouling boats. Furthermore, its presence in ports and marinas suggests that transfer on the hulls of vessels (both recreational and commercial) may be a likely pathway of introduction and spread. It has been estimated that there are approximately 120 major marinas and 40 commercial harbours throughout the UK that have environmental conditions (e.g., water temperature and salinity) suitable for carpet sea squirt survival. Spread within, to, and from Wales via hull fouling is therefore highly likely, as Wales supports a high intensity of both recreational boating and commercial shipping. Additionally, the disposal directly into the water of scrapings from boat hulls could fragment the carpet sea squirt and so facilitate further spread. It is therefore advised that boats with visible or heavy fouling should be lifted or trailered out of the water and taken to a suitable location for cleaning. This should ideally be a contained area of hard-standing ground with appropriate drainage above the high-tide line.

Notably, the Welsh records of the carpet sea squirt have been associated with marina and port infrastructure. In a 2008 survey of Holyhead Marina, the carpet sea squirt was found to have colonised the flat sides and underside perimeter of the pontoons and was growing on mooring chains and on species attached to mooring chains. The transfer of structures or equipment such as pontoons between marinas / harbours, if not adequately cleaned and dried (see [Control Methods](#)), could risk transferring colonies to a new location. Additionally, any in-water cleaning or non-waste capturing shore cleaning of structures or equipment may risk fragmenting a colony and facilitating its spread. Fouled infrastructure can also be damaged and broken up in storm events, representing a further risk of spread (e.g., damage to Holyhead Marina pontoons in [Storm Emma](#) in 2018).

Hitchhiking on equipment and on shellfish stock

The carpet sea squirt could hitchhike on or foul both shellfish and aquaculture or fishing equipment and infrastructure. The occurrence of the carpet sea squirt on intertidal oyster trestles in Ireland has been linked with the importation of oysters from France. The potential movement of stock for relaying which has been contaminated with the carpet sea squirt

could therefore result in its spread. Aquaculture facilities provide artificial structures and surface that could promote settlement and growth of the carpet sea squirt, which can result in these farms acting as ‘stepping stones’ for further spread.

Ballast and bilge water

Ballast water is taken up by some vessels (e.g., cargo ships and some ferries) to aid stability while underway. The carpet sea squirt can be taken up, in larvae or fragment form, in ballast or bilge, transported and then introduced into new locations when the ballast or bilge water is discharged. While the larval stage is relatively short and may therefore be prone to dying on route, settlement on other substrates within the ballast or bilge water is possible, thereby extending the life of the organism. Fragments of the carpet sea squirt colonies suspended in water can survive for up to three weeks and can subsequently reattach to, and grow on, new surfaces.

The UK merchant shipping (control and management of ships' ballast water and sediments) regulations 2022, which implement the requirements of the international convention for the control and management of ships' ballast water and sediments (2004), mandate the offshore exchange of ballast water or the treatment of ballast water to remove or destroy organic matter (e.g., larvae, phytoplankton) before the water can be discharged. If this legislation is enforced, this would decrease the risk that this pathway poses as a primary introduction pathway for the carpet sea squirt. Bilge water on smaller leisure crafts, however, is not regulated. Similar to ballast, bilge water is taken up at one location and moved to another location, releasing water and associated propagules into the receiving environment, potentially introducing new species. As such, these smaller leisure craft are typically viewed as secondary pathways of spread within the UK.

Dredging and hopper water

The dredging of materials on which the carpet sea squirt grows (e.g., hard surfaces such as gravel, cobble and boulders) could facilitate its dispersal. However, the mechanical stress caused by the movement of such materials, and potential desiccation during the processes, may limit survival. The carpet sea squirt does not typically grow on soft, unstable, substrates such as sand or mud, so the dredging of these substrates is unlikely to aid movement. Due to the carpet sea squirt's wide environmental tolerances (e.g., to temperature, salinity and water depth changes) survival is likely if introduced to a new location.

Another potential vector is hopper water. Instead of ballast, some barges used to transport dredged sediment will fill the hopper (cavity that holds the sediment) with water to stabilise the vessel. In this way, the pelagic larvae or colony fragments of INNS (such as the carpet sea squirt) could be taken into the hopper. Once the barge arrives at the dredging site, the hopper water is released.

For dredging operations to take place in Wales, a licence is required from NRW unless conditions for an exemption are met. As part of the licence application, a marine INNS [Biosecurity Risk Assessment and Management Plan](#) must be completed. The risk assessment

requires consideration of the presence of INNS at both the source and receiving sites as well as the INNS at the locations previously visited by the dredging vessel. Management measures must be identified which would mitigate the risk of introducing or spreading INNS.

Marine litter

The carpet sea squirt can grow on a wide variety of surfaces, including plastics. Therefore, colonies or colony fragments attached to floating marine litter could be carried to new locations. For more information, see the [2024 González-Ortegón](#) paper on floating plastics as a vector.

Additional pathways

Reintroduction and restoration projects that transplant organisms (e.g., native oysters or seagrasses) from one location to another risk spreading INNS, including the carpet sea squirt. For example, there could be small colonies attached to translocated organisms.

However, biosecurity considerations are already being made for many of these projects, with protocols/handbooks published that outline necessary practical steps to prevent the spread of INNS. For example, the European Native Oyster Restoration Handbook contains a chapter on biosecurity, providing information on protocols that should be followed when translocating oysters, shell cultch and other substrates (see [Chapter 4 of the handbook](#)). An example of biosecurity protocols in practice can be found in the biosecurity plan for the Firth of Forth native oyster reintroduction trials. In addition to outlining cleaning/sterilisation procedures, it also states that a donor site would be rejected (i.e. not used in the project) if there was known to be carpet sea squirt present (see [Annex 4 of the Forth Oysters Biosecurity Plan](#)).

A note on natural spread

Although not a human-mediated pathway, natural spread by currents can facilitate the dispersal of a species beyond the initial site of introduction in its non-native environment. The larval stage of the carpet sea squirt has such a short duration (less than 24 hours) that natural spread of larvae beyond a few metres is unlikely, although high water flow rates could extend that range. However, colony fragments can be suspended in the water and moved by currents to new locations. These fragments can survive for up to three weeks, reattaching to suitable substrate when they come into contact.

What are its impacts?

Environmental

Competition and habitat alteration

The carpet sea squirt grows rapidly, enabling it to monopolise space and so outcompete and displace other organisms, such as bivalves, sponges, and other sea squirts. The carpet sea squirt can also grow on top of other organisms, which can reduce their ability to feed, leading to poor health and ultimately death.

Its rapid growth and wide tolerance for different habitats allows the carpet sea squirt to occupy vast areas. At Georges Bank in the USA, the carpet sea squirt was recorded covering at least 230 km² of pebble gravel habitat (see the [2007 Valentine paper](#)). When the carpet sea squirt dies off in colder months it can create large patches of bare sediment. The outer covering of the carpet sea squirt is acidic, providing a chemical defence against predation. This also prevents other species from growing over it or larvae from settling on it, reducing available space and thus reducing biodiversity. Vast areas can be turned into monocultures of the carpet sea squirt. The impacts to key marine protected features, which support diverse and important ecological niches, are outlined in Table 2.

Table 2. Impacts to key protected marine features by the carpet sea squirt. References to the papers and reports used for this table can be found in the *Bibliography*.

Key protected features	Impacts on protected features by the carpet sea squirt
Seagrass and Zostera habitats	Grow on seagrasses leading to reduced light, impacting growth
Bivalve beds	Foul and smother the multifaceted surfaces provided by the bivalves (including oysters, mussels and scallops)

Biofouling: overgrowth and smothering

The carpet sea squirt is a habitat generalist, able to foul hard-shelled sessile communities, seagrasses and seaweeds, artificial surfaces and mixed hard seabed substrate alike. Dense and expansive colonies of the carpet sea squirt may prevent predators, like crustaceans and fish, from accessing their prey below (e.g., worms) and from reaching substrates used for egg laying. The carpet sea squirt is found at particularly high densities on gravel substrates which many fish species use as spawning and nursery grounds. As a result, the carpet sea squirt can impact commercially important species such the Atlantic herring (*Clupea harengus*) by restricting access to this substrate.

The carpet sea squirt can directly cause the deterioration (and death) of bivalves by encapsulating and smothering them. It has also been observed fouling eelgrass, which may lead to reduced growth because of a reduction in light reaching the leaves. Biofouling by the carpet sea squirt can also indirectly increase the rates of predation on other organisms. Sea

scallops (*Placopecten magellanicus*) encrusted with the carpet sea squirt were unable to swim as far or as high as non-encrusted scallops, making them vulnerable to predation, and resulting in them reaching exhaustion more rapidly (see the [2011 Dijkstra paper](#)).

Socio-economic

The growth of the carpet sea squirt on artificial substrates results in increased cleaning and maintenance costs, thereby increasing the operational costs for port and marina authorities. However, these costs are difficult to quantify. Work to eradicate the carpet sea squirt in Holyhead Marina, Wales (UK) was estimated at £375,000 in year 1 and £400,000 in year 2 for treatment and follow-up monitoring (see the [2011 Nimmo report](#) and details Welsh eradication efforts below). The fouling by the carpet sea squirt is likely to cause increased cleaning and maintenance costs for fishers since it can be particularly difficult to remove from fibrous materials such as nets and lines. However, removal is important since the carpet sea squirt can substantially increase the weight of socks, ropes and lines (and other equipment) and is likely to impede water circulation which is essential for bivalve health. In New Zealand, \$807,000 has been spent trying to eradicate the carpet sea squirt from economically important habitats such as mussel lines (see [CABI information](#)).

The aquaculture industry is vulnerable to impacts from the carpet sea squirt since shellfish farms often feature a variety of artificial substrates, like cages and trestles, that are suitable for colonisation. Aquaculture sites are also typically positioned in sheltered bays and food (in the form of suspended organic material) is often plentiful, creating an ideal environment for carpet sea squirt growth. By fouling cultured bivalves, the carpet sea squirt can smother the openings of bivalves where water (and therefore food) enters, and potentially reduce the reproductive output, growth, and health of bivalves and ultimately result in death. Costs to the industry can result from the loss of stock and from increased cleaning requirements.

The carpet sea squirt has been recorded growing on shellfish such as oysters, mussels and scallops. Furthermore, the presence of the carpet sea squirt can prevent the settlement of other larvae, like those of the commercially important bay scallop (*Argopecten irradians irradians*) and sea scallop (*Placopecten magellanicus*) due to its acidic properties (as seen in Georges Bank, New England, see the [2007 Valentine paper](#)). This may limit the subsequent population recruitment to fisheries, causing longer-term economic losses or uncertainties to businesses and individuals. The impacts to commercially important species are outlined in Table 3.

Table 3. Impacts to commercially important species from the carpet sea squirt. References to the papers and reports used for this table can be found in the [Bibliography](#).

Commercially important species	Impact to the species from the carpet sea squirt
Scallops (including <i>Pecten maximus</i>)	Fouls shells, decreasing swimming ability and affecting growth and survival
Mussels (including <i>Mytilus edulis</i>)	Smothers mussels, causing death; partially encapsulates, reducing growth; reduced space for larval settlement

Commercially important species	Impact to the species from the carpet sea squirt
Oysters (including <i>Magallana gigas</i>)	Overgrows shell clusters leading to reduced shell growth, mishappen growth and death; grows on aquaculture growing equipment (e.g., bags), restricting water flow and food; reduced space for larval settlement
Finfish (including Atlantic herring (<i>Clupea harengus</i>))	Fouls the seabed, decreasing foraging ability of predators and restricting access to spawning grounds

Carpet sea squirt in Wales: National context

Distribution of the carpet sea squirt

In the UK, the carpet sea squirt is predominantly found along the south coast of England with some records on the east coast of Northern Ireland and in Holyhead, Wales. Figure 4(A) shows the distribution of carpet sea squirt records in the UK and Figure 4(B) shows the distribution of the carpet sea squirt in Wales, as reported to the [NBN Atlas](#). It is important to note that if there is no record present, it may not mean that there is no population present. There may be a lack of monitoring, a delay in reporting or a lag in communication.



Figure 4. Maps of recorded and confirmed carpet sea squirt occurrences in (A) the UK and (B) Wales from open source NBN Atlas data (OGL and CC-BY licences) as of February 2025. Contains public sector information licensed under the Open Government Licence (OGL) v3.0, Public Domain Dedication (CC0) v1.0, Creative commons with attribution v4.0 (CC-BY). Data rightsholders, data providers, and dataset references are provided in [Data References](#).

In 2008, the carpet sea squirt was recorded at Holyhead Marina, Wales. Eradication was attempted in 2009 / 2010 but was unsuccessful, although surveys of Welsh marinas in 2014 did not detect it elsewhere in Wales (see [eradication attempts in Wales](#)). In Holyhead, the carpet sea squirt appears to be confined to the marina. In August 2023, the carpet sea squirt was detected within the Milford Haven Waterway in multiple locations.

Figure 5 shows the distribution of the carpet sea squirt in the Milford Haven Waterway as surveyed between August and November 2023. Extensive colonies were found under arches near Pembroke Port and smaller colonies were found on the shore out towards Carr Rocks (see Figure 6). The area under the arches is shaded and current-swept which is ideal for sea squirts in the intertidal zone. The largest colonies were greater than 50cm in diameter with a leathery tunic that could be peeled off the rock surface. The colonies were found on boulders, weeds and on the vertical surface of the archway structures.



Figure 5. Map of carpet sea squirt records in Milford Haven Waterway up to November 2023. Yellow polygons show the search areas completed (August – November 2023), green points show presence of carpet sea squirt.



Figure 6. Carpet sea squirt growing on weeds and rocks on the foreshore adjacent to several commercial marine operations in Pembroke Dock, Milford Haven. Photo taken in November 2023.

MPA features at risk from the carpet sea squirt

The potential impact of the carpet sea squirt to MPA habitat features in Wales was assessed in [NRW Report 454](#) and then mapped (see figure 7) in the [NRW evidence report](#) “Marine Protected Areas: Features at risk from marine invasive non-native species” (pending publication). The mapping shows that the risk to habitats from the carpet sea squirt varies across Welsh waters. As previously mentioned, sediment habitats are considered largely unlikely to be suitable for this species and as these habitats are extensive in the intertidal and subtidal, concern was considered to be minimal or minor across large areas. However, areas of rocky and biogenic habitat may be suitable. Habitats were assessed as being of ‘minimal concern’ to ‘major concern’ depending on the likelihood that small or large areas within the habitats would be fouled.

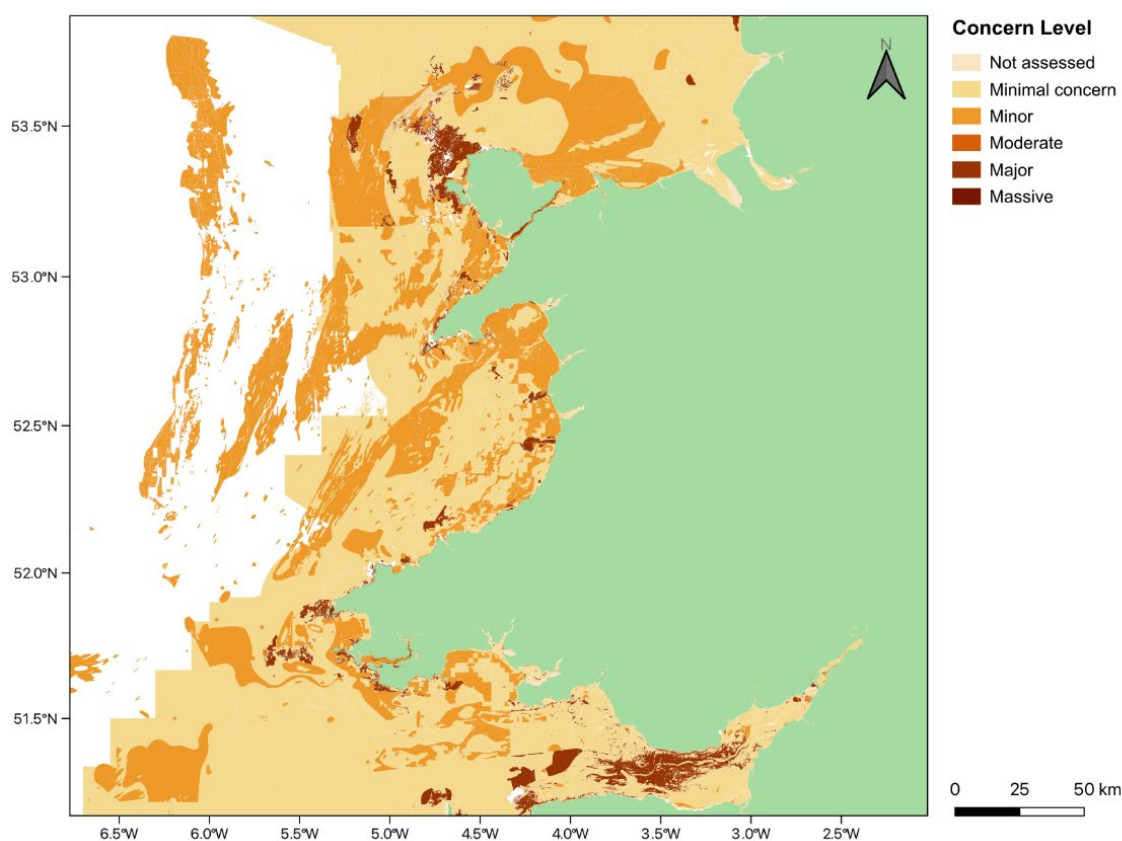


Figure 7. Habitat risk (concern level) from the carpet sea squirt, *Didemnum vexillum* based on the assessment carried out in the NRW evidence report: ‘Assessing the impact of key Marine Invasive Non-Native Species on Welsh MPA habitat features, fisheries and aquaculture’.

INNS and the law

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

- [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.
- 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](#).

There are pathway-specific regulations that would relate to the movement of this species. Please see the relevant PAPs on the [Wild Seas Wales website](#) for more information.

Under the legislation and policy summarised above, the carpet sea squirt has been assessed for the risks and impacts it poses to UK marine ecosystems. The outcomes of these assessments are listed in Table 4 below. The GB Non-native Species Secretariat (GB NNSS) commission and approve risk assessments of NNS to determine the risk of them entering, establishing, spreading and causing impacts in GB. These risk assessments support the Invasive Non-native Species Regulations and the wider GB legislative framework. Additionally, the Welsh Government's [Marine INNS Priority Monitoring and Surveillance List for Wales](#) summarises the INNS that are referred to directly in relevant legislation and/or their supporting documents. The list identifies INNS present in Wales and those that are "horizon species" (species that are not yet present but are likely to arrive in the future). The document also includes an assessment of the risk posed by INNS in Wales (in terms of invasiveness, spread and impact), which draws upon risk assessments developed by the GBNSS.

Table 4. Species impact and risk assessments for the carpet sea squirt.

Assessment	Legislative driver	Carpet sea squirt assessment outcome
INNS prioritisation (according to invasiveness, impact and spread)	Marine Strategy Regulations 2010	UK Priority Species
WFD UK Technical Advisory Group classification of aquatic alien species (according to their impact level)	The Water Environment Regulations 2017	High Impact
GB NNSS risk assessment	The Invasive Non-Native Species Regulations 2019. Wider GB legislative framework.	High Risk Entry Risk = Very Likely Establishment Risk = Very likely Spread = Rapid Impacts = Massive
Marine Invasive Non-native Species Priority Monitoring and Surveillance List for Wales	Marine Strategy Regulations 2010	High Risk

Challenges to INNS management

1. Eradication of an INNS in the marine environment is extremely difficult. It is more feasible to focus efforts on preventing the introduction of the carpet sea squirt to new locations, as much as is possible, and reducing or controlling existing populations so as to reduce the risk of its spread.
2. In the marine environment, control strategies that are undertaken to reduce the density of an INNS population can be both expensive and indiscriminately destructive, risking impacts to non-target species. Cost-benefit analyses must be undertaken in addition to considering the local ecosystem and minimising any impacts to protected species or sites. Habitat Regulations Assessments (HRAs) may be required for control strategies within European Marine Protected Areas.
3. Specific challenges for the control and eradication of carpet sea squirt may include: the species rapid growth and ability to regenerate from small colonies, fragmentation of colonies or uncontrolled larvae dispersal during removal acting as a mechanism for further spread, the large-scale effort and logistics needed to physically remove/treat colonies, difficulty in identifying the species potentially makes post-control monitoring uncertain, and a current lack of species-specific treatment options.
4. The carpet sea squirt's ability to spread through fragmentation creates challenges for any removal attempts. Dislodged fragments can be carried by currents and settle in new areas, potentially accelerating its spread, which makes management of carpet sea squirt extremely challenging.
5. Feasibility studies should be undertaken for potential control and eradication programs to assess the efficacy and impacts of different methodologies (see Table 6). However, accessing funding for these studies can be a potential barrier.
6. Identification of carpet sea squirt can be extremely difficult, with DNA analysis currently being the only certain method for identification. This can be time consuming and costly, which can result in delays to any form of rapid response.
7. There are limitations and challenges for the enforcement, regulation and monitoring of national legislation, e.g., the Ballast Water Convention.

Biosecurity to manage the carpet sea squirt

The following sections present recommendations for actions that, if undertaken, will improve biosecurity in Welsh marine areas and, ultimately, reduce the risks posed to the environment and economy from the carpet sea squirt.

Who are the key stakeholders?

Within the context of this SAP, a stakeholder is anyone who uses, benefits from or is responsible for (e.g., managing, protecting or regulating) the marine environment. Biosecurity to address the carpet sea squirt requires engagement and action at national, regional and local scales by stakeholders including, but not limited to individuals, businesses, marina and harbour managers, statutory bodies, authorities (i.e., bodies with powers to introduce, amend and enforce regulations, legislation and policy).

For the successful implementation of the actions recommended in this SAP and across the [biosecurity framework](#), stakeholders must work together to engage, support and secure resources where needed.

Examples of authorities and stakeholders are included below.

Authorities

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

National stakeholders

- Non-regulatory government bodies (e.g., Cefas)
- Management bodies for protected sites (e.g., National Trust)
- Recreational boating governing bodies (e.g., RYA Cymru)
- Environmental charities and Non-Governmental Organisations (NGOs) (e.g., the Marine Biological Society and Wildlife Trusts)
- Commercial operations governing bodies, organisations and groups (e.g., International Maritime Organisation, Maritime UK, Association of British Ports)
- Major landowners (e.g., the Crown Estate)
- Commercial fishing associations (e.g., Welsh Fisherman's Association, WFA-CPC)

Local stakeholders

- Local environmental groups;
- Aquaculture site owners, managers and operatives
- Port authorities and commercial shipping operators (including dredge operators);
- Marina managers and harbourmasters
- Commercial boat businesses and operations (including shipping and dredging)
- Point of sale (e.g., marine brokers, boat manufacturers, chandleries)
- Commercial fishers
- Recreational boating tour operators and event organisers;
- Recreational anglers, shellfish gatherers and bait collectors
- Recreational clubs and boating organisations (including boating event organisers)
- Individual users

Recommended strategic actions for authorities

Table 5 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 INNS in Wales. 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 stakeholders](#)).

Table 5. Recommended strategic actions for authorities to address the introduction and spread of marine INNS via all pathways in Wales. The ID letters SS (Species Strategic) denote that the actions are aimed at addressing the management of species, differing from the ID letters PS (Pathway Strategic) in the Pathway Action Plans (PAPs) that are aimed at addressing the management of pathways.

ID	Strategic action	Purpose
SS-1	Develop a national (Welsh) position statement for key marine INNS	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. • 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 surveillance and monitoring, 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 INNS 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 management strategies.

ID	Strategic action	Purpose
SS-2	Review existing legislation	A review should be undertaken of current legislation in Wales and the wider UK relating to key INNS (and their 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 introducing / amending legislation relating to key INNS and their pathways in Wales.
SS-3	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.
SS-4	Identify and prioritise high risk areas/locations for marine INNS introductions and impacts	Species and pathway risk assessments are a valuable tool for identifying and prioritising high-risk locations and more effectively allocating resources. Data gathered from previous reports (e.g., NRW 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 risk assessments is currently limited and further data collection is required.
SS-5	Develop a national plan for monitoring marine INNS	A national plan should develop a standardised approach to monitoring marine INNS and their pathways and implementing inspection programs in high-risk locations (see SS-4). The

ID	Strategic action	Purpose
SS-5	Develop a national plan for monitoring marine INNS	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 stakeholder from all levels. A cost-benefit analysis could also be undertaken to ensure that the implementation of inspections will not damage Welsh businesses.
SS-6	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 newly recorded INNS. 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, June.2025).
SS-7	National level curriculum	Lobby the Department for Education to include information on INNS and biosecurity in the national curriculum. Advice should be provided for the development of appropriate materials.

ID	Strategic action	Purpose
SS-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 (BES IS SIG). 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.
SS-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 carpet sea squirt 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 components in this SAP are designed to complement those outlined in the PAPs and other SAPs. They can serve as a foundation for creating a new biosecurity plan or modifying and enhancing existing procedures. Following stakeholder engagement, high-level ‘priority issues’ have been identified for each component. These are intended to inform the initial context for developing tailored action for each component rather than represent specific objectives. Biosecurity implementation is an ongoing process. The components aim to support and sustain stakeholder-level actions over time.

A pathway-based approach to biosecurity is more robust and appropriate than a species-based approach as addressing a pathway will address all the species that might be moved via that pathway. However, species-specifics can still be considered and integrated into a BAP (or used in support actions from a PAP) for an area/site where the carpet sea squirt has been identified as a high-priority species, either for its management or for the prevention of its introduction or spread.

These components are:

1. [Understanding roles and legal responsibilities](#)
2. [Information, guidance and research on the carpet sea squirt](#)
3. [Raising awareness](#)
4. [Biosecurity processes and procedures](#)
5. [Species management](#)
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 INNS.

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 S1 to S4), 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 industries to develop appropriate and achievable policy, without undue impact to Welsh blue growth and 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 newsletters or other communications to relevant stakeholders (e.g., updates from harbour authorities or from national recreational governing bodies) 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 • Include an overview of key INNS legislation and policy in e.g., public communications, employee information and club announcements.

2. Information, guidance and research on the carpet sea squirt

To ensure that information and guidance on the carpet sea squirt and relevant biosecurity within Welsh marine areas are consistent, high-quality and appropriate for all stakeholders and sectors.

PRIORITY ISSUE: Information 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.

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. Factsheets should be created to raise awareness of the carpet sea squirt among key stakeholders. The factsheets should contain information on the impacts the species causes and what actions can be / are being undertaken to minimise it's further spread. Existing species factsheets from the GB NNSS could be used as a basis for any Wales-specific resources. Factsheets should be developed in co-ordination with sector representatives to ensure that the information is relevant and outlines best practice. Language and writing style should be considered for different stakeholder groups / audiences – it is critical that information is presented appropriately and accessibly.	• Develop and update sector-specific factsheets on the carpet sea squirt. Identification sheets of several marine species can be found on the GB NNSS website. • Produce training resources on the carpet sea squirt that can be provided to other stakeholders. • Print (and disseminate) ID guides (such as the Welsh and English ID guide booklets produced by NRW) to as many relevant stakeholders as possible (e.g., local groups, aquaculture operations, points of sale). (see useful resources)

Responsible stakeholder	Guidance for Development of Actions	Example actions
Authorities continued	The fact sheets should be disseminated to key stakeholders in all parts of Wales, particularly to those undertaking any monitoring work. They should be made available on-line and in printed format to ensure consistency of messaging. A simple identification guide could also be included with instructions on how sightings (or suspected sightings) of the species should be reported. Species surveys and mapping of occurrence records should be undertaken to establish where populations currently are. Species distribution maps will provide insight into where the carpet sea squirt is present and absent, and therefore where it may be at risk of spreading from and to. Pathway analyses and risk assessments should be carried out to identify hot spots (see recent, related work above). This, in turn, will allow for effective prioritisation of resources for biosecurity and surveillance (either in relation to population management or prevention).	• Keep ID guides up to date, accounting for new and horizon INNS. • Map the distribution of carpet sea squirt and carry out pathway analyses to facilitate resource prioritisation

Responsible stakeholder	Guidance for Development of Actions	Example actions
All stakeholders	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. All stakeholders should ensure that resources are appropriate for their sector, reviewing national guidance and tailoring outputs to reflect relevant operations and risk factors. Authorities could consider leading a consultation with other stakeholders on the production/review of these guidance documents. A simple presentation (e.g., PowerPoint slide pack) should be prepared and made openly available for all to use. The slide pack should contain a summary of key points on carpet sea squirt identification, how it's introduced and spread, the impacts it has, and how it should be reported. A simple script or recording should be included in the notes section to aid presenters. Use should also be made of the carpet sea squirt specimens that are included in the INNS kit from the National Museum of Wales, detailed in Useful Resources. The 2020 Tillin report; Assessing the impact of key Marine Invasive Non-Native Species on Welsh MPA habitat features, fisheries and aquaculture, concluded that “there is a lack of understanding regarding its [carpet sea squirt] impacts by altering benthic community structure and decreasing benthic foraging ability of larger, mobile predators”. Additionally, it was noted that the carpet sea squirt “is not widely established in the UK on natural habitats and there are key uncertainties in the extent and magnitude of colonisation”. Further research is required to address these knowledge gaps and enable a more informed approach to planning, prioritisation and control schemes.	• Refine existing biosecurity guidance to increase relevance for different sectors. • Provide identification training aids for the carpet sea squirt. • Undertake research to fill knowledge gaps in understanding of carpet sea squirt risk factors. • Conduct investigations into the sources of existing and newly recorded carpet sea squirt populations. • 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
All stakeholders continued	Investigations into the sources of carpet sea squirt populations should also be prioritised. The investigations should comprise a genetic component to determine the sources and pathways of recently established population and identify priority pathways for biosecurity. Research councils (e.g. NERC, BBSRC) could be influenced to highlight this area of investigation as a priority programme. Investigations should be undertaken in collaboration with universities and researchers to provide scientific robustness. These evidence needs should be noted in NRWs marine evidence needs process and flagged as potential collaborative university student projects.	See actions above.

3. Raising awareness

To facilitate and encourage the active sharing of information and guidance on the carpet sea squirt among all stakeholders within Welsh marine areas.

PRIORITY ISSUE: Some stakeholders operating within Welsh marine areas are not aware of INNS (including the carpet sea squirt) 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.

Responsible stakeholder	Guidance for Development of Actions	Example actions
Authorities	Authorities should ideally be a primary source for INNS and biosecurity information in Wales. 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 • Include links or QR codes to online resources (including ID guides and factsheets) with communications. Where appropriate, stock/disseminate paper copies of resources.
All stakeholders	It should be noted that raising awareness actions are expected to overlap significantly across all marine PAPs, SAPs and BAPs. Therefore, it is critical that authorities, along with local and national stakeholders take a holistic approach by integrating/coordinating 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. 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	• Engage in any national awareness raising campaigns such as 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).

Responsible stakeholder	Guidance for Development of Actions	Example actions
All stakeholders continued	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. The useful resources within this SAP 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, 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. Developing awareness raising materials that highlight the economic and environmental risks of the carpet sea squirt (based on the information provided in this SAP and the useful links) can provide targeted warnings where the carpet sea squirt is a particular problem (e.g. ports and marinas where the sea squirt is resident); although, it is recommended that targeted awareness raising of individual species is created and disseminated in parallel with general INNS awareness raising.	• Become familiar with the existing carpet sea squirt guidance and resources. • Share information resources with other stakeholders as widely as possible. • Provide ad hoc information/facts on the carpet sea squirt and INNS in general to staff, colleagues, members of the public, customers etc. • Add in a link to biosecurity information on the GB NNSS website in staff updates. • Put up ID posters of the carpet sea squirt on notice boards or 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. • Integrate carpet sea squirt information into education activities with schools or school-age groups (e.g., rockpooling trips)

Responsible stakeholder	Guidance for Development of Actions	Example actions
All stakeholders continued	Biosecurity signage is known to be successful in raising awareness. Where appropriate (e.g. onshore aquaculture facilities, staging areas, recreational launches etc.) signage can be installed in visible (to employees 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 anti-fouling (e.g., the suitability of different coating types and how they should be maintained). It is important to educate and enthuse younger generations on issues relating to INNS and biosecurity. Engagement with local schools or school groups to explore the most suitable way in which the topic of INNS and biosecurity can be incorporated into national education. Materials and resources produced as part of component 2 should be shared with educators. Marine INNS and biosecurity could be integrated in the Ocean Literacy Strategy for Wales 2025 project “Y Môr a Ni”. This strategy should be promoted.	See actions above.

4. Biosecurity processes and procedures

To improve INNS biosecurity procedures, especially those which reduce the risk of introducing and spread the carpet sea squirt, being undertaken by stakeholders, ensuring consistency and efficacy.

PRIORITY ISSUE: Biosecurity may not be routinely undertaken by stakeholders and there is a perceived lack of appropriate guidance.

Responsible stakeholder	Guidance for Development of Actions	Example actions
All stakeholders	A pathway-based approach to biosecurity, rather than a species-based approach, is often taken preferentially as it means that all species associated with that pathway can be managed at the same time. This can improve efficiencies in cost, time and effort. In this way, all stakeholders operating within the Welsh marine environment are encouraged to implement or enhance biosecurity procedures. However, biosecurity could also be prioritised in areas where the carpet sea squirt is present. At the most basic, INNS biosecurity can be achieved simply through ‘Check Clean Dry’ procedures (see GB NNSS information). But stakeholders operating within areas where the carpet sea squirt is present should consider: • More frequent hull and equipment cleaning and antifouling. • Cleaning equipment on land ensuring that waste is not allowed to re-enter the water. • <u>Do not attempt to remove the species from structures whilst still submerged</u> 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 stakeholders may already implement effective INNS biosecurity	• Authorities could define and provide support to national and local stakeholders for the implementation of improved biosecurity. • Review and update existing codes of good practice (e.g., for aquaculture) • Develop codes of good practice for all activities/operations in the Welsh marine environment. • Consult and collaborate with all sectors 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.

Responsible stakeholder	Guidance for Development of Actions	Example actions
All stakeholders continued	measures (e.g. aquaculture operators). Enhancements can leverage existing best practices, integrate example practical biosecurity actions (see Table 6), or adopt innovative approaches tailored by operators themselves. Best practice for marine sectors has been created as part of the RAPID LIFE project. Codes for good practice in aquaculture have already been developed, e.g., the Code of Good Practice for mussel seed movements from the Menai Strait Fishery Order Management Association (MSFOMA). Reviews and updates should be carried out with a process of consultation with aquaculture operators to ensure that the code appropriately reflects practical and operational conditions as well as implementing improvements to biosecurity. Information should be included on which INNS to look out for, how to report sightings and communication protocols <u>Appointment of Biosecurity Managers or Champions</u> For operations of varying scales, Appointing a biosecurity manager or champion can be beneficial for the different sectors that are relevant to most pathways, keeping in mind the operational scale. 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.	• 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. • Ensure innovative approaches and updated best practice is shared within the industry

5. Species management

To effectively manage (i.e. control or eradicate) the carpet sea squirt.

PRIORITY ISSUE: Removal of carpet sea squirt is challenging and presents a considerable additional risk of spread. Coordination of control efforts and guidance for stakeholders could be improved, and efficacious methods for removal could be researched, developed and shared with stakeholders.

Responsible stakeholder	Guidance for Development of Actions	Example actions
All stakeholders	Removal of carpet sea squirt is challenging and carries a significant risk of causing further spread. This INNS can regrow from small fragments or spawn when disturbed. Manual removal from in-water structures should not be attempted without ensuring the use of an appropriate method. Recommended control methods can be considered (see Table 6), but expert guidance with detailed planning and risk mitigation should be sought before any removal efforts are undertaken. The potential environmental impacts, financial costs, and health and safety considerations must be factored into all control measures. Funding sources for further research should be considered and shared, with research councils like NERC and BBSRC prioritising invasive species management. Collaborative projects with universities will ensure scientific robustness, and NRW's marine evidence needs process should highlight invasive species as a research priority. University student projects should be encouraged to address knowledge gaps.	• Conduct investigations into novel control methods and the efficacy of current methods for the carpet sea squirt • Where feasible, develop control plans for known populations of the carpet sea squirt

Responsible stakeholder	Guidance for Development of Actions	
All stakeholders continued	Coordination and guidance for stakeholders must be improved to ensure best practices are followed in all management efforts. For example, clear guidance should be provided on how particular methods should be deployed, with any marine licencing or need for approvals identified. Guidance on how to monitor and assess efficacy and management endpoints should also be considered. A structured plan should outline yearly objectives such as population reduction, containment, or eradication. It should define responsible stakeholders, control methods, agreed actions, milestones, success indicators, timelines, and funding strategies. Regular reviews should assess progress, refine strategies, and integrate new research findings. A structured and collaborative approach will help mitigate the impact of carpet sea squirt, protecting marine biodiversity and economic interests.	See actions above.

6. Monitoring and reporting

To establish a robust understanding of carpet sea squirt distribution in Welsh marine areas and facilitate the early detection of new introductions or spread.

To ensure that carpet sea squirt 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 carpet sea squirt 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	To understand the distribution of the carpet sea squirt within Wales, monitoring of both existing populations and locations where the carpet sea squirt is not currently known to have invaded is required. Existing populations should be identified, prioritised and consistently monitored to understand population growth. To further the understand of rate of spread from known populations and facilitate rapid response high-risk (hot spot) locations may also be prioritised for monitoring. Surveillance of such high-risk locations where the species is yet to be detected will be essential in triggering rapid response processes. Ideally monitoring should be of a consistent effort and persistent at a regional level for comparability between years. It is suggested that monitoring at locations considered as high risk should be funded to ensure quality and consistency. Citizen scientists, including individuals, NGOs, charities and local action groups should be engaged with and encouraged to report sightings of the carpet sea squirt.	- Promote and encourage the use of INNS reporting / recording platforms. - Check Welsh INNS biosecurity communications for opportunities to collaborate on monitoring efforts. - Consider proactive INNS monitoring through citizen science programmes. - Borrow the marine INNS workshop kit to run training in identification. The kit is comprised of preserved specimens and information sheets and can be borrowed from Amgueddfa Cymru (see Useful resources).

Responsible stakeholder	Guidance for Development of Actions	Example actions
All stakeholders continued	As the carpet sea squirt can be difficult to definitively identify, a robust monitoring strategy should include the training of more ID specialists and the creation of a network of specialists or DNA analysis services. A quantitative PCR assay already exists for carpet sea squirt (Gargan et al., 2022). NRW evidence report 645 used this assay to continue work to develop and test methodologies for eDNA monitoring of marine INNS and the report includes recommendations for future work (Ironsides et al., 2023). The NRW INNS identification guide (links in Useful resources) is clear and concise and includes information on how to report marine INNS. This guide should be disseminated and maintained to facilitate effective reporting. However, surveillance and reporting should still generally target all INNS and be coordinated at a national level rather than focusing on individual species. Although, providing awareness materials and supplementary carpet sea squirt identification guides at high-risk locations, or in reference to high-risk operations, can support prioritised monitoring efforts. Although this component aims to increase the INNS monitoring and surveillance effort by stakeholders, it should be noted that INNS monitoring is multi-faceted and there is an expectation that authorities and local and national stakeholders should take an integrated approach to monitoring. 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 etc.) should consider implementing regular monitoring for INNS/priority species.	• Promote opportunities for integrated or collaborative INNS monitoring efforts. • Conduct regular monitoring for the carpet sea squirt

Responsible stakeholder	Guidance for Development of Actions	Example actions
All stakeholders continued	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. 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 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].	See actions above.

Responsible stakeholder	Guidance for Development of Actions	Example actions
All stakeholders continued	 Potential INNS sightings can also be reported directly to NRW at: invasive.non.native@naturalresourceswales.gov.uk 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.

7. Collaborative working

To improve the collaboration between all stakeholders within Welsh marine areas and 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 stakeholders 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 and inter-stakeholder collaboration are crucial. 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 working can be missed due to limitations in communication, leading to duplicated effort and gaps

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 stakeholders 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.	• 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

Control and management methods

Table 6, contains a list of control methods for the carpet sea squirt that have been used elsewhere and identified from available literature. These methods may be employed to prevent the spread and reduce the abundance of INNS populations. **Inclusion in this table is by no means an endorsement of any of these methods as some methods listed below could have detrimental effects on the surrounding environment and wildlife. Any control action that is taken for the carpet sea squirt should be done so following 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) and appropriate disposal of carpet sea squirt material and treatment waste should always be considered. Marine licenses and Habitat Regulations Assessments may also be required to undertake any of the following control methods.

Table 6. A list of control methods for the carpet sea squirt that have been utilised elsewhere and are reported in scientific literature. The references used can be found in the [control and management table's references](#) section of the bibliography.

ID	Action	Information
C-DV-1	Covering with uncontaminated sediment	This method aims to smother carpet sea squirt with uncontaminated sediment and cause mortality. Through this process, potentially large colonies of carpet sea squirt could be destroyed in specific locations, limiting spread and impact. A sediment depth coverage of 100 mm has proven effective. This approach may require a dredging and disposal license from the Marine Management Organisation or NRW.
C-DV-2	Exposure to freshwater	This method aims to cause carpet sea squirt mortality as, like many marine species, it is intolerant to freshwater (colonies will start to die in salinities less than 20psu). Through this approach, colonies of carpet sea squirt could be removed from, or destroyed on equipment and removeable infrastructure, limiting its spread and impact. The equipment/infrastructure should be removed from the marine environment and brought onto land or into an area where run-off will not re-enter the water. The freshwater could be applied by a hose (taking care that all run-off water and debris is collected) or the equipment/infrastructure could be submerged in a receptacle containing freshwater.
C-DV-3	Heat treatment	This method aims to cause carpet sea squirt mortality and kill carpet sea squirt colonies on infrastructure, limiting spread and impact. Structures should be removed from the water and the colonies burned using a liquified petroleum gas burning torch.
C-DV-4	Drying	This method aims to desiccate carpet sea squirt and cause mortality. Infrastructure should be removed from the water and left until it is fully dry. This should ideally be done during warm sunny weather to maximise desiccation and expose carpet sea squirt to UV light.

ID	Action	Information
C-DV-5	Physical removal	This is a process by which colonies of carpet sea squirt could be removed from specific structures and shellfish, limiting spread and impact. Where possible, the structures covered in carpet sea squirt should be removed from the water. The carpet sea squirt should be peeled from the substrate by hand or removed using a scrubbing brush. Pressured hot or cold water could also be used. Fragments should not be put back into the water. If cleaning can only be done in the water, this may be subject to marine licensing, Natural Resources Wales should be contacted for further advice. All removed carpet sea squirt material should be disposed of appropriately. As an additional measure, the structures from which the species has been removed should be left to dry before being returned to the water (see C-DV-4). Be aware that physical disturbance (stress) can cause the species to spawn. Fragments of carpet sea squirt can also easily spread and colonise areas elsewhere.
C-DV-6	Encapsulation	Encapsulation creates anoxic conditions and causes mortality. It reduces the risk of the carpet sea squirt spreading during this control process by creating a barrier. Plastic is wrapped around infrastructure or covers the seabed. High-grade geotextile fabric, plastic silage covers, or plastic wrap should be used and it should be ensured that the plastic is wrapped as tightly as possible. Plastic with the smallest possible pore size should be used to prevent the escape of propagules. For infrastructure treatment, bags rather than wrap could be used where possible to ensure full encapsulation. Excess water in the plastic bags is then pumped out. The plastic is removed once all organisms are dead.
C-DV-7	Direct biocide application	Biocides desiccate / poison the carpet sea squirt, causing mortality and thus limiting its spread and impact. The fouled infrastructure is removed from water and the surface allowed to dry as much as possible to prevent dilution of the biocide before spraying. It is then sprayed with a biocide such as vinegar (acetic acid), bleach (calcium hypochlorite or sodium hypochlorite) or hydrated lime (calcium hydroxide). The surface is then rinsed with freshwater, which is retained, preventing run-off into the environment.
C-DV-8	Encapsulation / bunding with biocide, salt brine or freshwater	Encapsulation with the addition of a chemical treatment improves and accelerates the effect of encapsulation alone, causing carpet sea squirt mortality. A biocide such as vinegar (acetic acid), bleach (calcium hypochlorite or sodium hypochlorite) or hydrated lime (calcium hydroxide) is added to encapsulated or banded water. Alternatively, the salinity may be altered to a level that carpet sea squirt cannot tolerate. The salinity of the encapsulated / banded water surrounding the affected surface can be increased by adding salt brine (sodium chloride or calcium chloride) or lowered with the addition of freshwater.

ID	Action	Information
C-DV-9	Oyster bag turning	Oyster bag turning can reduce colonisation by the carpet sea squirt. Oyster bags in the intertidal zone are turned as regularly as possible. This exposes both sides of the bag to less favourable conditions for carpet sea squirt growth and survival (prolonged exposure to air and UV light). If during this process carpet sea squirt is detected, the bag should be removed, cleaned and dried, ensuring no fragments re-enter the water.
C-DV-10	Direct biocide application to aquaculture species (shellfish)	Biocides desiccate / poison the carpet sea squirt, causing mortality and thus limiting its spread and impact. Aquaculture species (shellfish) colonised by the carpet sea squirt could be temporarily immersed in a biocide such as vinegar (acetic acid), bleach (calcium hypochlorite or sodium hypochlorite) or hydrated lime (calcium hydroxide) and then rinsed in seawater or freshwater. However, immersion in the biocide may cause mortality to the aquaculture species.
C-DV-11	Targeted biocides	Although there are limited biocides which specifically target carpet sea squirts, research and regulatory approval in this area is ongoing. For example, BioBullets have been developed which encapsulate a toxic chemical in an inert substance. These are ingested by filter feeders such as carpet sea squirt causing them to die. BioBullets can be produced to be fairly species specific so as to minimise non-target species impact; however, this does not currently appear to offer a definitive solution. BioBullets or yet to be developed products could possibly be used in the future as a biocide for the carpet sea squirt, but further research and development is needed.
C-DV-12	Biocontrol	The aim of biocontrol is to increase predation on the carpet sea squirt. Native predators such as sea urchins and winkles could be added to oyster bags to increase levels of carpet sea squirt predation. However successful biocontrol relating to the carpet sea squirt has not yet been demonstrated and biocontrol could be associated with non-target impacts.

Eradication attempts in Wales

The carpet sea squirt was first found in Wales in 2008 in Holyhead marina. A large-scale eradication attempt took place in Holyhead marina in Wales between 2009 and 2013 in this relatively contained site, where the carpet sea squirt was on artificial structures. This was led by the Countryside Council for Wales and funded by Welsh Government. This is considered one of the more robust eradication attempts in the UK. However, although initially, success looked possible, the area was quickly re-invaded. Currently, carpet sea squirt is still present in Holyhead marina and no eradication is ongoing at this site.

Winter 2009-2010

Isolation / stagnation methods (set and forget wrapping on chains) and purpose-built bags on pontoon structures were trialled. Calcium hypochlorite was added to bags to accelerate the process. Carpet sea squirt was apparently killed but rapidly recolonised on freshly treated surfaces. The net result was overall a slight reduction in abundance, but the species rapidly increased in abundance and distribution.

Winters 2010-2011-2012

All structures were treated over a short time period. Hypochlorite was used on all treatments including on chains (toxic socks) and all bags double-dosed (a week between doses). All floating structures (>7000m²) plus chains and vessel hulls simultaneously 'isolated' by enclosing in bags and plastic wrap. These were inspected and re-treated. This seemed to be successful shortly after the treatments.

By 2013, carpet sea squirt had re-colonised areas of the marina. An options paper was prepared by NRW which outlined further options. Although continued monitoring took place at the marina, lack of further funding and resources led to this eradication being drawn to a close.

In March 2018 Storm Emma almost completely destroyed the Holyhead marina, scattering most of the marina floating structures ashore in fragments or to the seabed. This considerably reduced the distribution and abundance of the species within the marina. A survey of the marina and surrounding areas in October 2018 to investigate whether the species had managed to spread via the debris concluded that the species remained confined to the remaining structures within the marina area. A survey of the marina and harbour area in Nov 2020 also came to the same conclusion.

Overall, this attempt at eradication was not successful and carpet sea squirt still remains at Holyhead marina (as of writing in 2025).

A full-time project manager was employed to co-ordinate the eradication programme. An assistant also supported the project. During the active phase of the project, dive teams of up to 8 people, including surface, boat and safety cover, were contracted. Costs were in excess of £800,000 (Holt, 2013; McKenzie, et al., 2017; Sambrook, et al., 2014).

Summary:

A large-scale eradication attempt took place in Holyhead marina in Wales between 2009 and 2013 in this relatively contained site, where the carpet sea squirt was on artificial structures.

However, although initially success looked possible, the area was quickly re-infected. Currently, Carpet sea squirt is still present in Holyhead marina and no eradication is ongoing at this site.

Trialling the use of ultrasound in controlling the carpet sea squirt (*Didemnum vexillum*)

Ultrasound is used commercially as a means to limit fouling, but its potential for use in biosecurity is untested and its efficacy in treating already fouled surfaces is unknown. This study carried out in 2024, aimed to determine the potential use of ultrasound in biosecurity, through its impact on the globally important non-native tunicate *Didemnum vexillum*. Commercially available ultrasound units ULTRACRAB were used in mesocosms in quarantine facilities to expose colonies of *D. vexillum* to varying lengths of ultrasound exposure. Preliminary work exposing colonies of *D. vexillum* to ten minutes, 60 minutes, 24 hours, and five days of ultrasound failed to show any impact on the growth and condition of *D. vexillum* compared to control conditions. Both treatments and controls showed a decline in *D. vexillum* growth, leading to a change in the way *D. vexillum* was fed during subsequent experimental ultrasound exposure. Experiments then examined the effects of 5- and 10-day exposure; both ultrasound treatments showed a decline in growth and condition of colonies which was significantly greater than under control conditions. The effect was greatest in the longer exposure period. Despite clear effects, colonies did not die and 7 days after termination of ultrasound, growth and condition was no different from control colonies. This experimental work shows that ultrasound has the potential to be used as a method of controlling *D. vexillum* but further work over longer time periods and field conditions is required. Assessment of impacts on larval and early stages may also be beneficial.

For further information please contact Professor Stuart Jenkins, Bangor University: s.jenkins@bangor.ac.uk.

Useful resources

- [GB NNSS carpet sea squirt identification guide](#)
- [GB NNSS carpet sea squirt risk assessment](#)
- [CABI Compendium carpet sea squirt information page](#)
- [Marine Life Information Network \(MarLIN\) carpet sea squirt information page](#)
- [Nature Biodiversity Network \(NBN\) Atlas carpet sea squirt records](#)
- [Welsh marine INNS priority list](#)
- [Natural Resources Wales marine INNS guide in Welsh](#)
- [Natural Resources Wales marine INNS guide in English](#)
- **Links to Pathway Action Plans (PAPs) and other Species Action Plans (SAPs)**

Links to the action plans listed below can be found on the [Wild Seas Wales website](#):

- Chinese mitten crab, *Eriocheir sinensis* SAP
- American slipper limpet, *Crepidula fornicata* SAP
- Trumpet tubeworm, *Ficopomatus enigmaticus* Species Action Plan
- American oyster drill, *Urosalpinx cinerea*, & Japanese oyster drill, *Ocenebrellus inornatus* SAP
- Recreational Boating (large boats) PAP
- Recreational Boating (small boats) PAP
- Recreational Activities PAP
- Commercial Shipping PAP
- Aquaculture PAP
- On-shore Fishing PAP
- Boat-based Fishing PAP

- **Marine Invasive Non-Native Species (INNS) Kit for Wales**

This kit was created with funding from European Maritime and Fisheries Fund and with support from NRW, Aberystwyth University and Wales Wildlife Trust. It is loosely based on the MBA's (Marine Biological Association, Plymouth) kit that was borrowed for an INNS workshop by the stakeholders in October 2022 and it was agreed that a kit for Wales would be useful. This kit can be borrowed as a whole or divided up into major groups and one part loaned out.

The kit consists of the following major groups:

- Algae (Seaweeds)
- Molluscs
- Sea squirts
- Bryozoans
- Crustaceans
- Other (Polychaetes, and anemone)

The kit may be borrowed by anyone who is running a supervised workshop for adults and it is an excellent way to train recorders who are looking out for Invasive Non-Native Species. It is free to borrow, but courier or transport costs, must be paid for.

It includes specimens, images, distribution data and species information that are included with each group of the kit. Images of the kit are included in the following pages along with approximate dimensions of it as a whole and divided into its separate subject groups.

To borrow the kit or any aspect of the kit please contact Anna Holmes (anna.holmes@museumwales.ac.uk).



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Appendix

Sector specific best practice advice posters produced by Natural Resources Wales in 2024, following confirmation of carpet sea squirt in Milford Haven.



Species Alert

Carpet sea squirt - *Didemnum vexillum*

Best Practice Advice for Aquaculture

This marine invasive non-native species (INNS) has the potential to cause negative effects on the marine environment and to aquaculture facilities, and therefore it is important that we act to reduce its further spread. This provides guidance for those with aquaculture facilities.

Bringing in Stock

- Check the stock origin site is free of Carpet sea squirt. Request details of the supplier's non-native species biosecurity plan (if one is available) to ensure all appropriate mitigations have been taken to avoid introduction of non-native species.
- It is advised that you undertake your own risk assessment when bringing stock into an area. Information and advice can be sought from NRW to assist with this.

Day to day work

- Check equipment and stock regularly for signs of obvious non-native species or anything unusual, especially Carpet sea squirt, and record sighting on iRecord or contact NRW for advice.
- It is best practice to have a marine INNS biosecurity plan for your farm. Keep this up to date with species like Carpet sea squirt. NRW can provide advice on this process.
- Train any staff to be alert to unusual growth in the marine environment, give staff basic identification training and ID guides ([Wales INNS guide](#), [NNSS *Didemnum* guide](#)) and encourage an open culture of reporting unusual sightings.
- If you identify Carpet sea squirt on your stock, or if you are cleaning trestles or equipment as part of your activities, we advise that you clean it away from the marine environment to avoid fragments going back into the sea causing further spread.

Moving stock between sites

- Where contamination by Carpet sea squirt is suspected, take photographs if its safe to do so and contact NRW for further advice. Record its extent on the farm.
- Carpet sea squirt can have a significant impact on shellfish aquaculture. If there is a risk you may have or suspect this species on your stock, avoid transfer for relaying until further advice has been sought from NRW and appropriate cleaning has taken place to avoid further spread to new areas.



Recording

- Report any sightings of Carpet sea squirt to the iRecord [app](#) or [website](#)
- If this is not possible please let NRW enquiries line know Tel 0300 065 3000 (Mon-Fri, 9am-5pm) or email enquiries@naturalresourceswales.gov.uk

Your sightings are vital to keep track of this species.

Recording all your sightings on iRecord.



Species Alert

Carpet sea squirt - *Didemnum vexillum*

Best Practice Advice for Infrastructure

This marine invasive non-native invasive species (INNS) is a heavy fouling species and has the potential to cause negative effects on the marine environment. Therefore, it is important that we act to reduce its further spread. This provides guidance for those with infrastructure at their site.

Advice to reduce the risk of spreading Carpet sea squirt

- If possible, regularly check any of your submerged infrastructure for signs of Carpet sea squirt, so that suitable biosecurity actions can be taken to reduce its spread.
- Ensure that marine biosecurity plans are kept up to date for your site and include consideration of Carpet sea squirt.
- Any equipment or infrastructure which is to be moved within or out of the site should be cleaned and dried thoroughly before transport.
- Be alert to unusual growth in the marine environment and highlight this to any staff. Give staff basic identification training and ID guides ([Wales INNS guide](#), [NNSS](#) [Didemnum guide](#)) and encourage an open culture of reporting unusual sightings.
- If any infrastructure or equipment with Carpet sea squirt is due to be cleaned, it should be done so by scraping and left to dry for at least 48 hours before placing back into the marine environment. Any growth removed should be kept away from slipways / drains to avoid it going back into the water causing further spread.



Reporting

- Report any sightings of Carpet sea squirt to the iRecord [app](#) or [website](#)
- If this is not possible, please let NRW enquiries line know Tel 0300 065 3000 (Mon-Fri, 9am-5pm) or email enquiries@naturalresourceswales.gov.uk

Your sightings are vital to keep track of this species.

Recording all your sightings on iRecord.



Species Alert

Carpet sea squirt - *Didemnum vexillum*

Best Practice Advice for Recreational Activities

This marine invasive non-native species (INNS) is a heavily fouling species and has the potential to cause negative effects on the marine environment. Therefore, it is important that we act to reduce its further spread. This provides guidance for those that undertake water based recreational activities.

Day to day activities

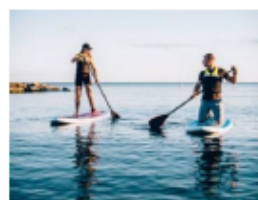
- Any infrastructure that is used as part of your activity (e.g. pontoons, ropes) should be checked regularly for Carpet sea squirt so suitable biosecurity actions can be taken to reduce its spread.
- Be alert to unusual growth in the marine environment and highlight this to any staff. Give staff basic identification training and ID guides ([Welsh INNS guide](#), [NNS Didemnum guide](#)) and encourage an open culture of reporting unusual sightings.

Moving to another area

- As your activities are likely to involve taking kit out of the water on a daily basis (e.g. paddleboards, kayaks etc), ensure all equipment / clothing / trailers are **Checked**, **Cleaned** and **Dried** before next use. Pay attention to damp, hard to access areas.
- Ensure that anything removed does not re-enter the water causing further spread.

Cleaning / Removing equipment from the water

- If using boats for your activity, clean and antifoul hull annually using antifouling paint.
- Ensure all boats / equipment are cleaned away from slipways and drains to prevent any scrapings going back into the marine environment causing further spread.
- Ensure all equipment/clothing/trailers are **Checked** carefully, **Cleaned** thoroughly and **Dried** before next use. Information can be found in [Check Clean Dry for boaters](#) / [Boating Pathway Action Plan](#).
- If equipment is going back into the water, clean it off carefully away from the water and leave to dry for at least 48 hours or longer if conditions are damp.



Reporting

- Report any sightings of Carpet sea squirt to the iRecord [app](#) or [website](#)
- If this is not possible please let NRW enquiries line know **Tel 0300 065 3000 (Mon-Fri, 9am-5pm)** or email enquiries@naturalresourceswales.gov.uk.

Your sightings are vital to keep track of this species.

Recording all your sightings on iRecord.



Species Alert

Carpet sea squirt - *Didemnum vexillum*

Best Practice Advice - Marinas and Boat Owners

This marine invasive non-native invasive species (INNS) has the potential to cause heavy fouling on boats and cause negative effects on the marine environment. Therefore it is important that we act to reduce its further spread. This provides guidance for boat owners / users and those that work in or use marinas.

Day to day activities

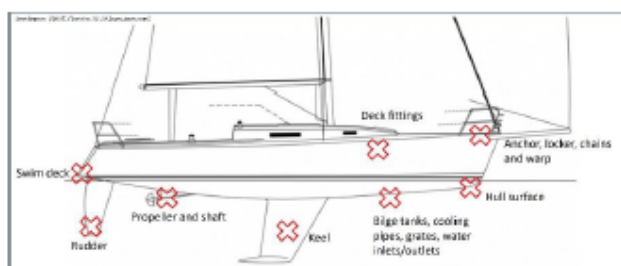
- Marina infrastructure (e.g. pontoons, ropes) should be checked regularly for Carpet sea squirt and vessels should be visually inspected so suitable biosecurity actions can be taken to reduce its spread.
- Be alert to unusual growth in the marine environment and highlight this to any staff. Give staff basic identification training and ID guides ([Wales INNS guide](#), [NNSS *Didemnum* guide](#)) and encourage an open culture of reporting unusual sightings.

Cleaning and removing boats from the water

- After removing your boat from the water for maintenance or winter storage, hulls and equipment should be cleaned carefully away from slipways and drains to prevent any potential INNS going back into the marine environment causing further spread.
- Any equipment due to be replaced in the water should be dried for at least 48 hours or longer if conditions are damp.
- Clean and antifoul hull annually using antifouling paint.

Moving between areas

- Ensure all equipment/clothing/trailers are Checked carefully, Cleaned thoroughly and Dried before next use.
- Further information can be found here [Check Clean Dry for boaters](#) and [Boating Pathway Action Plan](#)



Locations on a boat which should be checked for INNS

Reporting

- Report any sightings of Carpet sea squirt to the iRecord [app](#) or [website](#)
- If this is not possible please let NRW enquiries line know Tel 0300 065 3000 (Mon-Fri, 9am-5pm) or email enquiries@naturalresourceswales.gov.uk.

Your sightings are vital to keep track of this species.

Recording all your sightings on iRecord.



Data References

Table 7 Rightsholders and data providers for the open-source data downloaded from NBN Atlas for the purpose of this report.

Data Providers	Rightsholders
Centre for Environmental Data and Recording	Centre for Environmental Data and Recording
Marine Biological Association	Department of Agriculture, Environment and Rural Affairs
Natural England	iNaturalist & bernardpicton
Natural Resources Wales	Marine Biological Association
Porcupine Marine Natural History Society	Marine Biological Association, and Biological Records Centre
Seasearch	National Museums Northern Ireland
	Natural England
	Natural Resources Wales
	Porcupine Natural History Society
	Seasearch

Data Set References:

2004-2012 Bishop et al. Occurrence of non-native sessile invertebrates on the English coast by Marine Biological Association under licence CC BY. Conditions of use of dataset: No marina names (if deduced) should be published without the marinas explicit consent. Cite: Bishop, JDD, Wood, CA, Yunnice, ALE, Griffiths, CA. (2015) Unheralded arrivals: non-native sessile invertebrates in marinas on the English coast. Aquatic Invasions, 10.

Centre for Environmental Data and Recording (2023). iNaturalist records from Northern Ireland. Occurrence dataset on the NBN Atlas

Centre for Environmental Data and Recording (2023). Ulster Museum Marine Surveys. Occurrence dataset on the NBN Atlas

Centre for Environmental Data and Recording (2020) Northern Ireland Environmental Recorders occurrence dataset

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Natural England (2023). Natural England Marine Monitoring surveys. Occurrence dataset on the NBN Atlas

Natural Resources Wales. (2023) Marine Sightings & Miscellaneous Species Records from Natural Resources Wales (NRW), 2007 onwards. Occurrence dataset accessed through the NBNAtlas

Porcupine Marine Natural History Society (2020): Porcupine Marine Natural History Society Dataset. v2.2. Marine Biological Association. Dataset/Samplingevent. Occurrence dataset on the NBN Atlas. <https://doi.org/10.17031/zay9rc>

Records provided by DAERA marine species images, accessed through NBN Atlas website. (Open Government Licence (OGL) DAERA). For more information: <https://registry.nbnatlas.org/public/show/dr2113>

Seasearch (2023). Seasearch Marine Surveys in England. Occurrence dataset on the NBN Atlas

Verified marine records from Indicia-based surveys by Marine Biological Association and Biological Records Centre under licence CC BY. Released under DASSH terms and conditions – See <http://www.dassh.ac.uk/terms-and-conditions>