North West Wildlife Trusts

Monitoring invasive non-native species in marinas of North West England

Report to Natural England

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1. Introduction

Marine Invasive and non-native species (INNS) introduced beyond their natural geographical range are an increasing threat to native biodiversity, marine industry (such as aquaculture), and human health (Bax et al., 2003). For the purposes of this report all non-natives will be referred to as INNS[1].

Assemblages of marine INNS are largely composed of fouling invertebrates that are highly adaptable and thus proliferate under a range of environmental conditions. Typical fouling INNS include ascidians, barnacles, bryozoans and algae (Bishop et al., 2015). Such organisms can outcompete their native counterparts, spread disease, and impact marine infrastructure through fouling. Invertebrate INNS are readily transported around the globe by a host of human vectors, such as ship hulls or as planktonic larvae in ballast water (Hayes, 2002). Ports and harbours are key sites for the primary establishment of INNS, due to the abundance of artificial hard substrata which is readily colonised (Glasby et al., 2007). Studies have shown that floating artificial structures such as pontoons provide a habitat in which INNS flourish, allowing populations to establish and spread to adjacent areas by colonising other vessel hulls (Dafforn et al., 2009). Marinas are numerous along the UK coast and are often adjacent to ports. As they are largely composed of pontoons, marinas function as stepping-stones for the secondary spread of INNS. It is therefore an urgent priority to monitor their spread, so that new introductions and secondary spread can be recorded and managed appropriately by the relevant authorities. There is also relatively little public awareness of marine INNS, however informing marine stakeholders about species and risks could benefit monitoring and prevent further spread.

The Marine Biological Association (MBA) has previously monitored the spread on INNS throughout the UK coastline with dedicated Rapid Assessment Surveys (RAS) of marinas (Wood et al., 2016). For the western coast of England, the first surveys were conducted in 2009/10, and successive surveys of the same sites were carried out in 2015. These studies monitored INNS assemblages in six marinas on the West coast of England, and documented an overall increase in the number of INNS over time.

The North West has a relatively low number of INNS overall compared to other parts of the UK such as East Anglia (Wood et al. 2016). The INNS assemblage is similar to that of the Welsh coast (Wood et al. 2015b), which is unsurprising considering that Wales is the adjacent southern region. It is likely that the pathway of INNS range expansion around the UK is due to fouling biota using ports and marinas as stepping stones to gradually advance. Indeed, higher numbers of INNS on the east coast is probably a direct result of its proximity to mainland Europe, where introductions of INNS from further afield have originated (Bishop et al. 2014). Furthermore, it should be noted that North Western marinas have lock gates and low salinities, which could have also contributed to the low number of INNS found regionally compared with the East coast (Wood et al. 2016). Certain species are present in the region which poses potential socioeconomic impacts. For instance, the trumpet tubeworm *Ficopotamus enigmaticus* forms dense reefs that heavily foul hulls and pontoons, and hence are a serious concern with marina operators and users. Once established it can

[1] It is important to note that not all non-natives are actually "invasive". This is a term used to describe species that have become established and dominate aggressively. This can be from directly outcompeting native species, altering ecosystem processes and natural features (such as biogenic reefs), or interfering with marine industry such as aquaculture or shipping.

be difficult to eradicate INNS from marinas without costly direct removal. However, certain precautions such as regularly opening lock gates to allow exchange of seawater can reduce the larval retention of INNS and other fouling organisms, hence preventing superabundant populations from becoming established.

Monitoring marine INNS is essential as they are a descriptor of environmental status in the Marine Strategy Framework Directive (MSFD, see Appendix I) (European Commission, 2008), which aims to attain "Good Environmental Status" in European seas by 2020. In order to measure this status, baseline data must be collected on the descriptors and monitoring must be conducted regularly to highlight any changes. Descriptor 2 aims for "Non-indigenous" species (i.e. INNS) levels to be minimised. Furthermore, "pressure from invasive species" is listed as UK Biodiversity Indicator B6 (see Appendix II). Data from this project will therefore provide vital information on INNS geographical ranges, which can be utilised by governmental and non-governmental organisations with interests in managing the spread of marine INNS.

The primary focus of this project was to assess the current distribution of INNS in marinas, however two other aspects were also investigated. The Solway Firth Partnership provided settlement panels, which expanded the scope of the project to examine the recruitment of fouling INNS within marinas. Furthermore, this project seeks to investigate the extent of INNS awareness amongst marina users; as public reporting or recording could be a useful tool in monitoring INNS range expansion. Overall, this project has been undertaken in partnership with the Cumbria Wildlife Trust, Natural England, Solway Firth Partnership and the Marine Biological Association with the primary aim of updating the distribution of marine INNS in the North West of England.

1.1 Project aims

- To assess the current distribution of INNS in marinas in North West England using Rapid Assessment Surveys (RAS).
- To compare survey results with the MBA's 2015 Rapid Assessment Survey to determine the range expansion of INNS across North West England.
- To collect quantitative data of INNS recruitment in marinas during the summer by deploying settlement panels.
- To investigate the extent of marine INNS awareness among marina users.

2. Materials and Methods

2.1 Identification workshop

All survey staff attended specially devised species identification and survey methodology workshop before fieldwork was undertaken to ensure that all surveys were completed effectively and accurately with trained staff. This took the form of a theory session at Cumbria Wildlife Trust head office in Kendal, followed by a practical identification and survey workshop at Fleetwood marina. This site was chosen for training as it had the highest INNS diversity according the previous year's RAS. Minimal specimens were taken during training so that the INNS assemblage would not be drastically altered for the actual surveys. This training was delivered by Hayden Hurst (Cumbria Wildlife Trust) and Joanne Bayes (Natural England).

2.2 Study sites

Surveys were conducted in four marinas on the North West coast of England in the July 2016: Maryport, Whitehaven, Fleetwood and Liverpool (Figure 1). The chosen sites are located throughout the North West coastline, comprising two marinas in Cumbria, one in Lancashire, and one on the Mersey estuary. The primary reason for surveying these marinas was to analyse changes in INNS assemblages in these marinas over a year. This was possible as surveys performed by the MBA in 2015 were repeated. During the 2015 survey however, two other marinas were also surveyed on the West coast (Somerset and Preston) in addition to the four sites listed above. Somerset was omitted from the 2016 as this study was focused on the North West region. Although Preston is located in the North West, it is a freshwater site, and therefore outside the scope of this project. The RAS freshwater assemblage contains two target species: *Dreissena polymorpha* (Zebra Mussel) and *Dikerogammarus haemobaphes* (Killer Shrimp), both of which were recorded during RAS 2015.

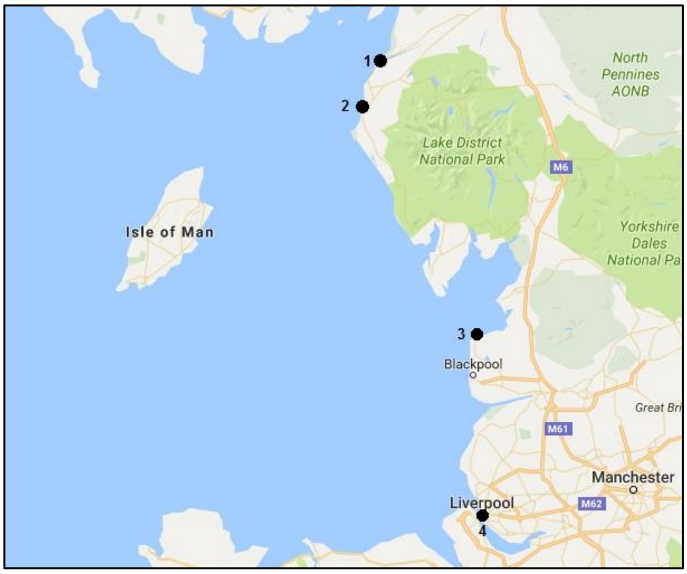


Figure 1: Locations of marinas surveyed in 2016: (1) Maryport, (2) Whitehaven, (3) Fleetwood, (4) Liverpool (Map data: Google 2016)

Each marina was contacted in advance to obtain permission to survey. The required safety documentation was then provided to each marina's Harbour Master, including: risk assessment, methods statement, COSHH assessment, contractor access forms, and proof of public liability and employer liability insurance.

2.3 Survey methodology

2.3.1 Rapid Assessment Survey

A target list of 37 non-native marine species was drawn up by the Marine Biological Association to be recorded during Rapid Assessment Surveys (RAS) (See Appendix III for full list and species descriptions (Wood et al. 2016)). The list is made up of an assortment of species previously identified in marina environments in the UK and species identified as likely arrivals (Wood et al. 2016). The surveys were carried out by CWT and NE staff following the MBA RAS protocol detailed below; this methodology has been used in marinas throughout the UK over a number of years including the RAS 2015 project. In addition many native species were recorded. The surveys of marinas in Cumbria (Maryport and

Whitehaven) were carried out on 11 July 2016. Lancashire and Mersey surveys (Fleetwood and Liverpool) were conducted on 14 July 2016. All surveyors had been trained in the RAS methodology and had attended a practical species identification workshop.

Surveys were undertaken regardless of tide state as sampling took place from the surface (i.e. from floating pontoons). At each site, the available pontoons were apportioned equally between surveyors. Staff remained in pairs for safety reasons, but worked independently in order to cover both sides of the pontoons. The teams surveyed for one hour, examining all epibiota on pontoons, boat hulls and submerged artificial substrates such as ropes, cages, and fenders. Natural substrates such as macroalgae were also pulled up for inspection. Hooks and scrapers were used if necessary to access such material.

The 15-minute interval (1-15, 16-30, 31-45, 45-60 min) in which each target species was first encountered was recorded, and an estimate of abundance made on a three-point scale (Rare-occasional, Frequent-common, Abundant-superabundant). Specimens were collected and preserved in ethanol to confirm findings and for discussion. At the end of the hour staff gathered to compare notes and record joint summary observations. An assessment of the adequacy of the one-hour search interval was made by checking that the rate of discovery of new taxa has fallen to a very low level by the fourth 15-minute interval. An additional 30 minutes of time was added when necessary at larger sites.

Abiotic measurements were also recorded after the RAS. Salinity was recorded with a refractometer, temperature with a thermometer, and turbidity was measured using a Secchi disk. On completion of the survey all equipment was washed with a disinfectant and then rinsed in fresh water to prevent transfer of INNS between sites.

Specimens were inspected later in the laboratory to make or confirm identifications, and where required specimens and photographs were sent to marine INNS researchers at the Marine Biological Association (Chris Wood and Dr John Bishop) for identification verification.

2.3.2 Settlement panels

Settlement panels were deployed in the marinas after RAS was complete, as this is a widely accepted method of measuring the recruitment of fouling organisms. They can also indicate which species are reproducing at the time of deployment. Results from panels can determine which INNS readily colonise clean substrata, which can be used as a proxy for vessel hulls, and hence indicate which species are more likely to spread to other sites. 150 X 170mm panels of corrugated plastic were suspended from floating pontoons with string at a depth of 50cm, thus simulating the conditions on the side of a pontoon. Fishing weights were affixed to the base to keep the panels submerged vertically in the water column (Figure 2). Five panels were deployed at each site and left for a period of 8 weeks, allowing epibiota to colonise them. The panels were then removed, preserved in 80% ethanol and taken to the laboratory for processing. Fouling assemblages growing on the panels were photographed, and then all taxa were identified under a dissection microscope, to species level where possible. To get a quantitative indication of the relative abundances of the fouling assemblage, the photographs were then used to calculate percentage cover using the open source analytical software Vidana 1.0.1be (Hedley, 2003). The mean percentage cover was calculated for each site.

Figure 2: A settlement panel after 8 weeks of submersion, showing the arrangement of fishing weights (Photo: Hayden Hurst, CWT)

2.4 Awareness questionnaire

Marina operators and interested marina users were spoken with during surveys to consider local knowledge and raise awareness of INNS. Furthermore, boat owners were questioned (see questionnaire, Appendix V) on their knowledge of marine INNS in order to gauge public understanding on the issue. This included questions on the users awareness and willingness to practise the GB non-native species secretariat “Check-Clean-Dry” procedure (Figure 3), as a method of preventing the spread of aquatic INNS via boating equipment (such as ropes) that have been submerged and colonised.

Figure 3: Check, Clean, Dry procedure for reducing the spread of aquatic INNS (GB non-native species secretariat, 2016)

3. Results

3.1 Rapid Assessment Survey

Details of the 13 recorded INNS occurrence and abundance data from 2016 and 2015 surveys are shown in Table I (see Appendix V for the complete RAS target species table). The environmental measurements of salinity, temperature and turbidity are reported in Appendix VI.

Table 1: Occurrence of fouling INNS at 4 sites on the North West English coast in 2015 and 2016. Notes: Abundance scores: Adapted and abbreviated SACFORN scale: 3 = Abundant/Superabundant, 2 = Frequent/Common, 1 = Rare/Occasional, Blank = Not present or not observed

		ASCIDIANS					BRYOZOANS			ARTHROPODS		POLYCHAETES	ALGAE		
YEAR	SITE CODE	*Styela clava*	*Corella eumyota*	*Botrylloides violaceus*	*Botrylloides diegensis*	*Aplidium cf. glabrum*	*Tricellaria inopinata*	*Bugulina simplex*	*Bugulina stolonifera*	*Austrominius modestus*	*Amphibalanus improvisus*	*Ficopomatus enigmaticus*	*Undaria pinnatifida*	*Codium fragile fragile*	**TOTAL INNS**
2016	Mary	1	1							2		1			**4**
	White									2	1	3			**3**
	Fleet	3	1	2	1	1	3	1	1	2			2	1	**11**
	Liv	3					2		2						**3**
2015	Mary	1	1							2					**3**
	White									2	1	3			**3**
	Fleet	3	1	2	1	1	3			1			1	1	**9**
	Liv	3					2		2						**3**

3.1.1 Species accounts

13 marine INNS were recorded during the surveys (Figure 4), with advice identification from Chris Wood and John Bishop of the MBA. The most frequently occurring species were Darwin's barnacle (*Austrominius modestus*) and Leathery sea squirt (*Styela clava*), both being present at three of the four sites.

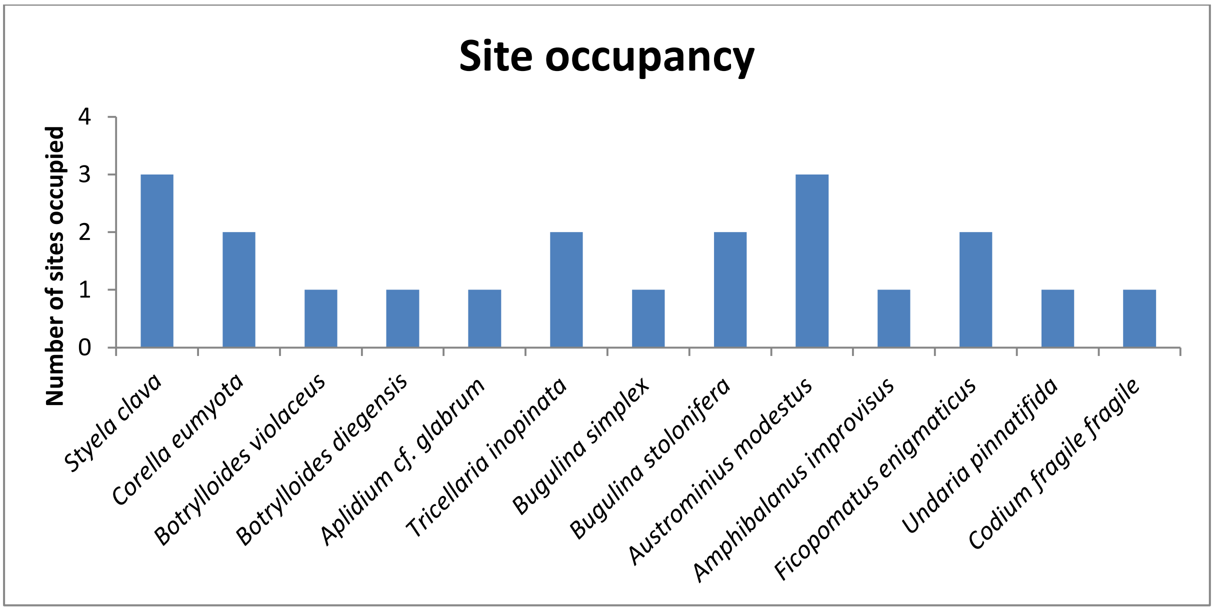
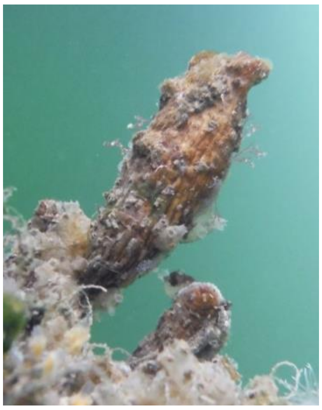


Figure 4: Frequency of occurrence of 13 INNS in four marinas of the North West coast

This extent of site occupancy is similar to that of native fouling biota such as the Vase sea squirt (*Ciona intestinalis*), the bryozoan *Cryptosula pallasiana* and the Purse sponge (*Sycon ciliatum*) (Wood et al. 2016). Other native organisms that were found included: *Conopeum seurati, Chaetomorpha linum, Chondrus crispus, Flustrellidra hispida, Electra pilosa, Balanus crenatus, Ascidella aspersa, Ascidella scabra, Semibalanus balanoides, Ectocarpus sp., Dendrodoa grossularia, Pterothamnion pulma, Botrylloides schlosseri, Ceramium sp., Rhizoclonium riparium, Pisidia longicornis, Corella parallelograma, Ulva intestinalis, Ceramuium sp, Ulva lacutaca, Sycon ciliatum, Mytilus edulis, Metridium senile,* and *Ciona intestinalis*.

Occurrence details and images of the 13 non-native species recorded are given below.

Styela clava (Leathery sea squirt)



A large and distinctive sea-squirt with a tough leathery brown tunic, *Styela clava* can reach up to 20cm long. It attaches to hard substratum with a long thin stalk and has two brown striped siphons located close together on the free end of the tunic. *Styela clava* was recorded in 3 of the 4 sites in the 2016 survey, with Whitehaven remaining the only unoccupied site. In both Liverpool and Fleetwood it was abundant/superabundant, being found on the majority of pontoons. In Maryport however, it was only occasional/rare.

Corella eumyota (Orange tipped sea squirt)

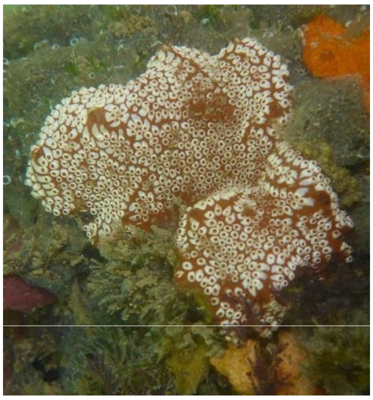
A smooth sea squirt often found in groups of individuals attached lying flat to the substratum with orange tipped siphons protruding. One siphon is located at the free end and the other is on the upper right part of the tunic. The gut forms a smooth curve around the bottom end of the tunic, which allows separation from morphologically similar native taxa such as *Ascidella aspersa*. *Corella eumyota* was recorded as occasional/rare in Maryport and Fleetwood, but remained absent from Whitehaven (the geographically intermediate marina between Maryport and Fleetwood).

Botrylloides violaceus (Orange cloak sea squirt)

A sheet forming colonial sea squirt, typically a bright single colour such as violet, red or orange, with individuals arranged in ovals or small rows. It can be distinguished by sizable and therefore conspicuous purple brooded larvae in the surface of the colony. This species was recorded at Fleetwood in previous years, and was recorded at Fleetwood alone again, with a SACFOR abundance of common/frequent.

Botrylloides diegensis (San Diego sea squirt)

This sheet forming colonial ascidian is difficult to distinguish from the non-native *Botrylloides violaceus* and the native *Botrylloides leachii*. Therefore only the recognized colour morphs were used to identify this species during surveys, as they are unique to the species. It was "occasional/rare" in Fleetwood marina, and has therefore not spread further since last year's survey.



Aplidium cf. glabrum

This colonial ascidian forms pale opaque colonies (with orange larvae sometimes visible) in cushion like arrangements on hard substrata. The species has not been officially identified taxonomically, but is widely accepted as a non-native species as the native *Aplidium glabrum* is a boreal species whose distribution is restricted to colder Scottish waters (Millar, 1966). The species has not spread any further in the North West since last year, as Fleetwood remains the only site occupied by *Aplidium cf. glabrum*, where it was occasional/rare.

Tricellaria inopinata (Tufty buff bryozoan)

A fast spreading and distinctive erect bryozoan that forms dense branched colonies up to 4 cm in height. Observation under a microscope reveals distinctive bifid spines and a lack of birds head avicularia, which are present in the superficially similar *Bugulina* sp. The species was Superabundant/abundant in Fleetwood marina and common/frequent in Liverpool marina, however it was found in these areas last year, showing it has not spread further.

Figure 10: *Tricellaria inopinata*, (photo: John Bishop, MBA)

Bugulina simplex

An erect straw coloured bryozoan that forms fan shaped tufts up to 3 cm tall. Branches are wider than many similar species, and can be composed of 2-6 zooids. *Bugulina simplex* was occasional/rare in Fleetwood marina, which is the first record of it in the North West of England.

Bugulina stolonifera

A grey-buff coloured erect bryozoan, forming dense branching tufts up to 4 cm in height, with zooids having birds head avicularia and a large spine on the distal margin. It was common/frequent in Liverpool, and was also recorded for the first time in Fleetwood (occasional/rare).

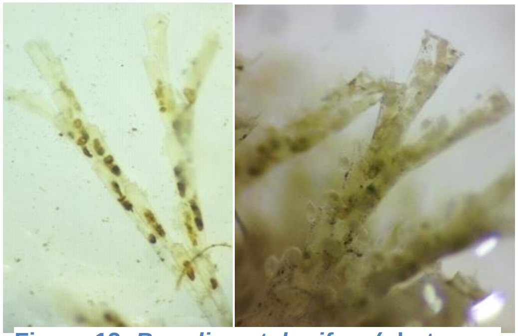


Figure 12: *Bugulina stolonifera* (photo: Hayden Hurst, Cumbria Wildlife Trust)

Austrominius modestus (Darwin's Barnacle)

This small white barnacle is well established in both natural and artificial substrata throughout the UK. It is distinguished by the diamond shaped opening and 4 outer shell plates, which differs from the native *Semibalanus balanoides* which possesses 6 outer plates. It is tolerant of low salinity and high turbidity conditions, which is indicative of its success in colonising marinas and estuaries. *A. modestus* was common/frequent at three out of four sites (Maryport, Whitehaven and Fleetwood), which reflects the same distribution found last year.

Amphibalanus improvisus (Bay barnacle)

A white shelled conical barnacle with 6 plates. Its orifice has a small tooth on the margin, and its width is usually more than half the height of the shell. This species can tolerate a range of environmental conditions including variable salinity. This year's survey results mirrored last year's, as *Amphibalanus improvisus* was recorded as occasional/rare in Whitehaven marina only.

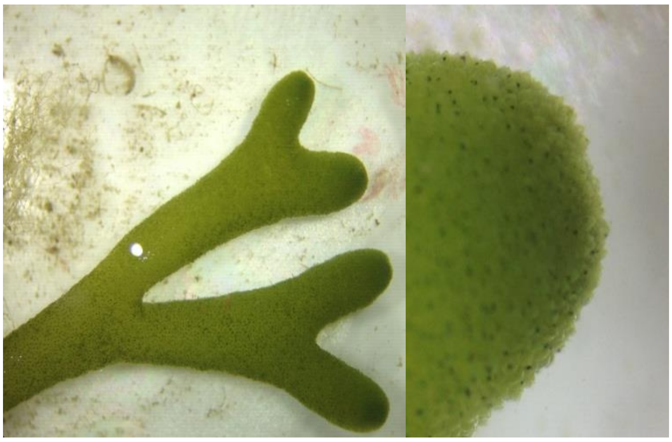
Ficopotamus enigmaticus (Trumpet tubeworm)

A polychaete that builds white calcareous tubes, forming densely packed colonies on shallow hard substratum. Individual tubes can reach 3mm in diameter and are easily distinguished by the presence of flared collars found periodically along the length of the tube. The worm itself feeds by extending orange tentacles from the orifice, but can retract the tentacles if disturbed to reveal a protective plug that is covered by black incurved spines. There was a superabundant/abundant population at Whitehaven marina, and was recorded for the first time at Maryport as occasional/rare.

Undaria pinnatifida (Japanese kelp, or Wakame)

A large species of kelp native to Japan, which has a broad frond with fingered edges and a conspicuous midrib. The holdfast is compact and root-like, and the stipe above it bears many folded reproductive frills. In the North West however, it has not spread further than Fleetwood marina, where is it was recorded last year. However it has increased in abundance within Fleetwood, being recorded as common/frequent as opposed to occasional/rare in 2015.

Codium fragile fragile (*Green sea fingers*)



A velvety species of green algae that is composed of cylindrical, finger-like dichotomous branches up to 10mm wide and 40cm long. It can tolerate a range of conditions in shallow water habitats, but favours sheltered water bodies such as marinas. Superficially it resembles native *Codium tomentosum* and *C. vermilaria*, but microscopic examination reveals that the utricles (the surface layer of miniature branches) of *C. fragile fragile* have pointed as opposed to rounded tips. It was occasional/rare in Fleetwood marina only, reflecting the same distribution and abundance as last year.

Species on the target list that were not recorded during these surveys were: *Asterocarpa humilis, Ciona robusta, Botrylloides* species 'X'*, Didemnum vexillum, Perophora japonica, Bugula neritina, Watersipora subatra, Schizoporella japonica, Diadumene lineata, Amphibalanus amphitrite, Hesperibalanus fallax, Caprella mutica, Ammothea hilgendorfi, Hemigrapsus spp., Urosalpinx cinerea , Crassostrea gigas, Crepidula fornicata, Hydroides ezoensis, Sargassum muticum, Grateloupia turuturu, Colpomenia peregrine, Chrysymenia wrightii, Bonnemaisonia hamifera*, and *Caulacanthus okamurae*. Only INNS already on the target list were recorded during the surveys, i.e. no newly introduced INNS were observed.

3.1.2 Site accounts

The total number of invasive non-native species in the region was 13, and the total number of INNS records (occupancy in each marina) was 21. The mean number of INNS recorded per site was 5.5 across all marinas in the North West. The site with the highest occupancy was Fleetwood marina, with 11 INNS recorded, whereas the marinas with lowest occupancy were Whitehaven and Liverpool with 3 species recorded at each site (Figure 18). See Table 1 for details of which species were found at each site.

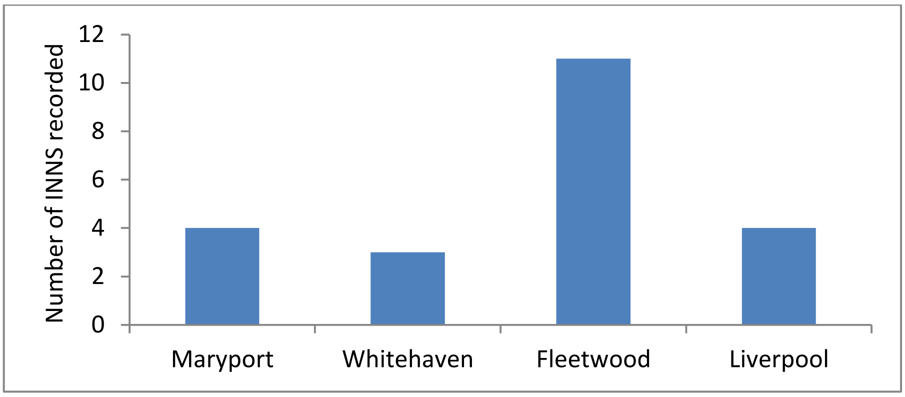


Figure 17: Counts of INNS recorded at sites along North West coast

3.1.3 Temporal changes

All four marinas surveyed during RAS 2016 project had also been surveyed in 2015 (Wood et al., 2016), which confirms a rise in the number of INNS records from 18 to 21, an increase of 17% within one year. Figure 19 displays these changes for each species, and also includes the data from RAS surveys conducted in 2009/10 for a long-term comparison (Bishop et al, 2015; Wood et al, 2016). The observed increases can be attributed to the occurrence of a species that were previously unrecorded in the North West (*Bugulina simplex*), and from the range expansion of two INNS that were already present in the region (*Bugulina stolonifera* and *Ficopotamus enigmaticus*).

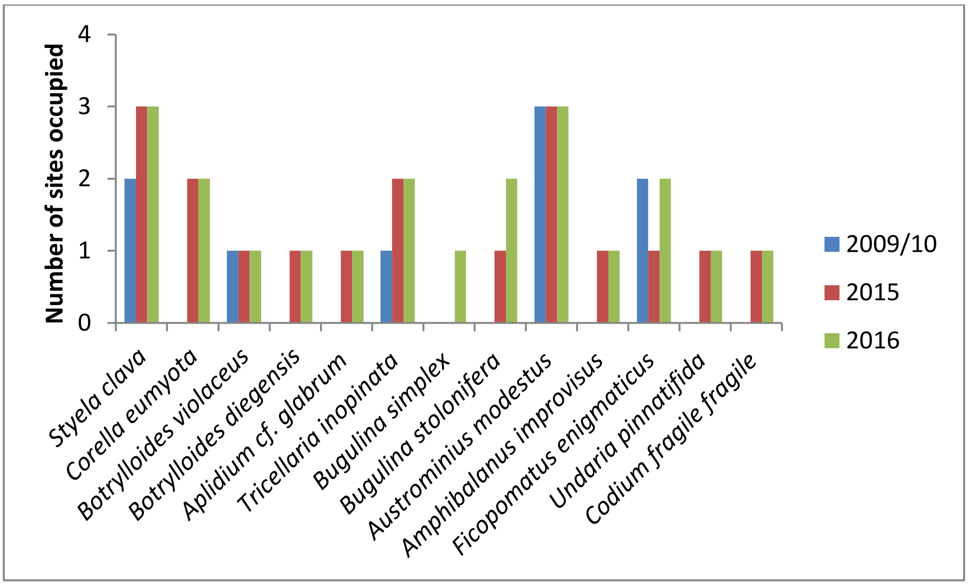


Figure 18: Change in occurrences of 13 species at North Western sites from 2009/10 to 2016

3.2 Settlement Panels

Five replicate panels were deployed in each marina (20 in total), however unfortunately not all panels were recovered after being submerged for eight weeks. All five panels were recovered from Whitehaven, and four from Fleetwood and Liverpool, but none were recovered from Maryport.

For all panels that were retrieved, fouling organisms occupied 100% of available space on their surfaces. Overall, the sites harboured similar suites of native species, and some of the same INNS. All INNS identified on the panels were also documented during the RAS (i.e. no previously unrecorded INNS were observed). Settlement panel assemblages yielded a lower species richness compared with RAS, with five INNS recorded on panels in total: *Tricellaria inopinata, Botrylloides diegensis, Austrominius modestus, Bugulina stolonifera* and *Ficopotamus enigmaticus.*

Fleetwood panel assemblages (Figure 20) were dominated by native juvenile green algae (*Ulva* sp.) with a mean cover of 61%. The next most abundant taxa on average were unidentified red filamentous algae (16.8%) and the non-native bryozoan *Tricellaria inopinata* (14.4%). Other less abundant species included the colonial ascidians *Diplosoma listerianum* (native, 4.1%), *Botrylloides diegensis* (non-native, 3%), *Botrlloides schlosseri* (native, 0.4%), and the barnacle *Austrominius modestus* (non-native, 0.4%).

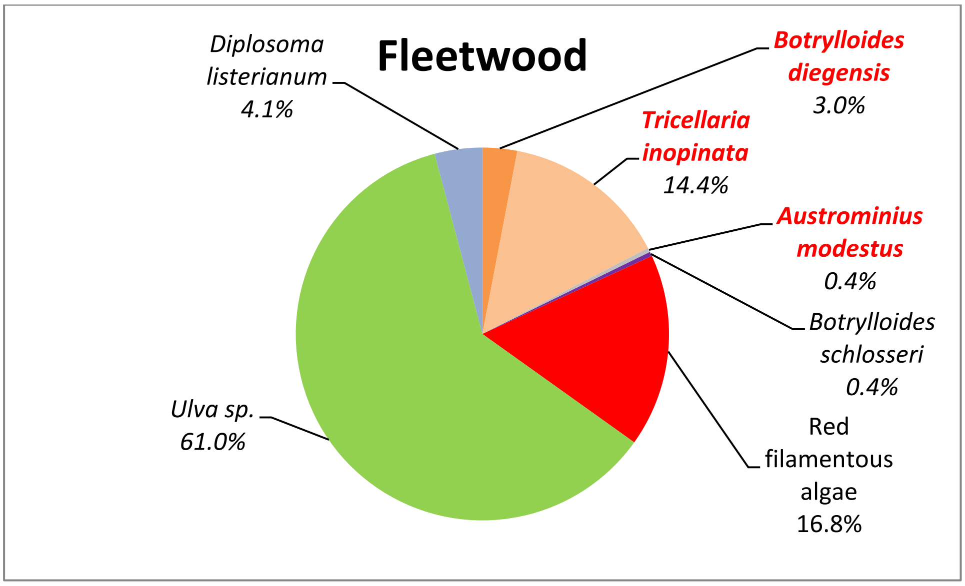


Figure 19: Mean percentage cover of species colonising settlement panels deployed in Fleetwood marina. INNS are highlighted in red.

Liverpool marina had a similar suite of dominant fouling organisms to Fleetwood; however the less frequently observed species differed (Figure 21). On average, the fouling assemblage colonising panels deployed in Liverpool was dominated by juvenile *Ulva* sp. (55.9%), followed by the non-native bryozoan *Tricellaria inopinata* which was also highly abundant (22.6%). Other taxa that were lower mean percentage cover included: unidentified red filamentous algae (7%), the green algae *Cladophora rupestris* (4.3%), *Corophium* sp. amphipods (native, 4.4%), bryozoans *Bugulina stolonifera* (non-native, 4.1%) and *Cryptosula pallasiana* (native, 0.4%), and the native ascidians *Botrylloides schlosseri* (0.8%) and *Ascidella aspersa* (0.6%).

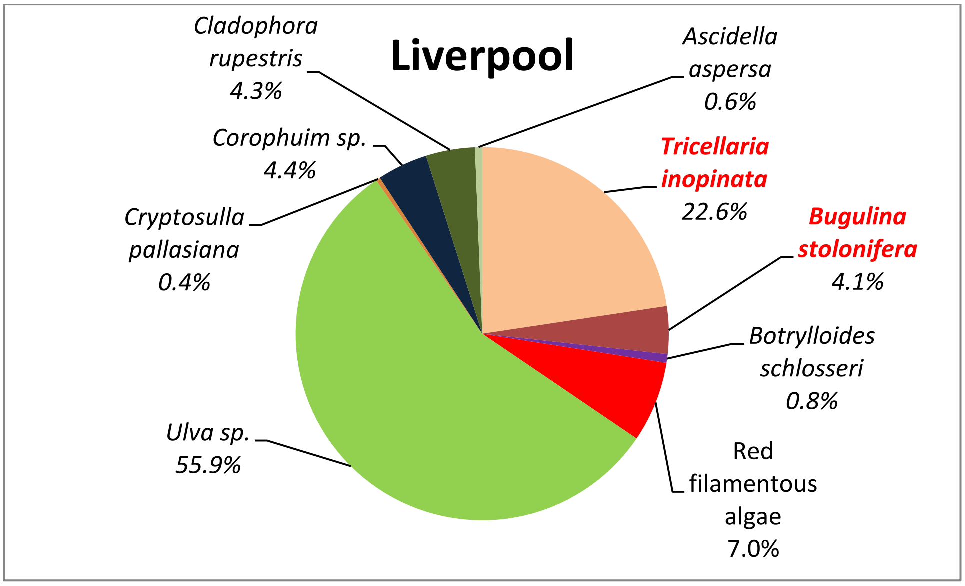


Figure 20: Mean percentage cover of species colonising settlement panels deployed in Liverpool marina. INNS are highlighted in red.

Two INNS were recorded on panels from Whitehaven (Figure 22), *Ficopotamus enigmaticus* and *Austrominius modestus*. In contrast with the other two sites, panels from Whitehaven marina were dominated by a different species of native filamentous brown algae, *Ectocarpus sp.*, which had a mean coverage of 49.9%. The species with next greatest coverage from the photographs was the encrusting native bryozoan *Conopeum reticulum* (29.5%), however in reality it occupied nearly 100% of the panel but the majority was concealed under the canopy of *Ectocarpus*. The invasive tubeworm *Ficopotamus enigmaticus* also occupied panels in relatively large densities, with 16.6% coverage on average. The remaining species accounted for a small proportion of the overall coverage, including: *Ulva* sp. (2.1%), unidentified red filamentous algae (1.6%), *Austrominius modestus* (0.2%) and *Corophium* sp. (0.1%).

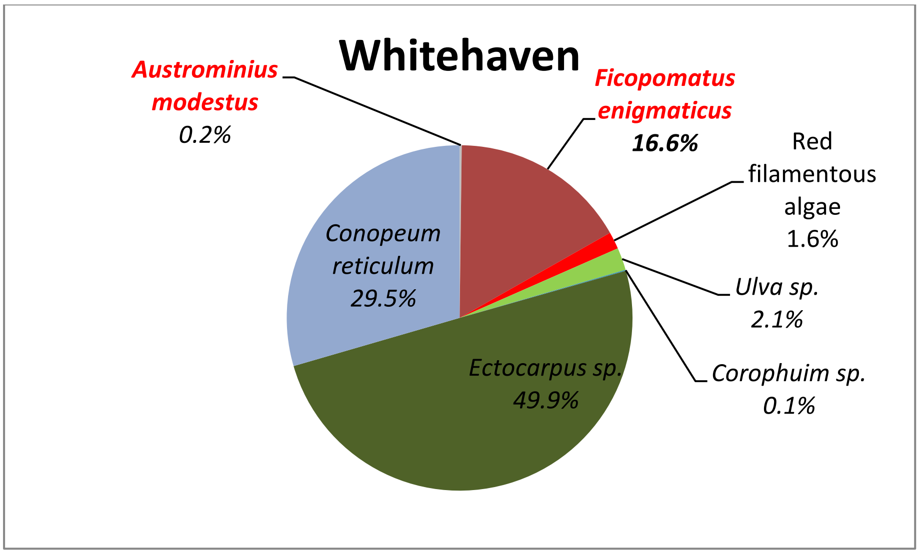


Figure 21: Mean percentage cover of species colonising settlement panels deployed in Whitehaven marina. INNS are highlighted in red.

Settlement panels were a new supplement to the RAS for monitoring INNS, and therefore there is no baseline data from North West England to compare these survey results with.

3.3 Awareness Questionnaire

Five marina users were asked questions on their awareness of INNS while surveys were conducted. This included two users from Whitehaven, and one from each of the other marinas. 3/5 users were aware of the presence of non-natives; however 3/5 also said that they could not recognise the difference between natives and INNS. Only users from Whitehaven marina (2/5) knew how to recognise a non-native species, the Trumpet Tubeworm, *Ficopotamus enigmaticus*. 3/5 users thought that INNS were likely to be a problem for the both environment and marine activities (mainly by fouling). 5/5 said that if they could recognise INNS then they would be willing to report them, and the most popular method of potential reporting was to email the marina authorities or operators. By contrast, only one user said they would be prepared to report sightings using an app such as SealifeTracker. Only 1/5 had heard of the “Check-Clean-Dry” procedure; however the remaining 4/5 said that despite not having heard of the scheme, they already perform the procedure as a matter of course to keep their equipment in good condition. Other notes from speaking to users from Liverpool included a verbal report of a population of *Ficopotamus enigmaticus* in the nearby Collingwood Dock, which is concerning as the species has not yet been recorded at this site.

4. Discussion and recommendations

4.2 Rapid Assessment Survey: significant observations

The colonisation of additional sites by *Bugulina stolonifera* and *Ficopotamus enigmaticus* since 2015 is a significant finding of these surveys. The erect bryozoan *B. stolonifera* was first recorded in the UK in the 1950s and its range has expanded throughout British harbours, although its exact distribution is still poorly understood (Ryland et al. 2011). Proliferation in marinas may be due to its feeding success in low flow velocities (Okamura, 1984), as marinas are typically sheltered water bodies. *B. stolonifera* therefore has the potential to affect local biodiversity by outcompeting native fouling organisms for food and space on hard substrata in artificial habitats; however such ecological interactions have not been thoroughly investigated. Despite potential ecological effects, *B. stolonifera* is unlikely to cause any significant socioeconomic issues through fouling that are not already presented by native *Bugulina* species (such as *B. avicularia*) and other fouling organisms.

Conversely, the reef-building trumpet tubeworm *Ficopotamus enigmaticus* presents a more serious socioeconomic threat. Whitehaven has a superabundant population of the tubeworm, which has led to major fouling of pontoons and yachts in marina. On some substratum the encrusting reef was 10cm thick (Figure 15), which would significantly impede vessel movement due to drag. Vessels berthed in the marina will consequently require their hulls to be scrubbed more regular basis, which is a costly process for boat users, and may subsequently impact the marina’s business by discouraging new clientele. Marina operators said that they had tried to reduce the population size by opening lock gates more frequently to flush out the worm’s larvae, however this appears to have had little success, and more drastic action may be required via scrubbing for eradication. *F. enigmaticus* populations display cyclic “explosions” and “crashes” according to environmental conditions and age however, and therefore an older colony with low larval recruitment could result in a natural decline in abundance (Thorp, 1994).

Aside from the existing population in Whitehaven, the tubeworm was recorded during our surveys in the adjacent Maryport marina (20km away), where it was previously absent. It is unlikely that there is a reproducing population in Maryport however, as only one individual was found. After speaking with Maryport marina staff, it was deduced that the pontoon where *F. enigmaticus* was found had a vessel from Whitehaven berthed there a few weeks prior to the survey. This strongly suggests that the vessel movement from Whitehaven has contributed to the range expansion of *F. enigmaticus.* If a population were to become established with full reproductive success, Maryport marina could face a similar threat to its business from excessive fouling. Despite this, it should be noted that there is considerably greater water flow through lock gates in Maryport which could result in lower larval retention than Whitehaven, and hence prevent the establishment of a superabundant population. Marina users were not aware of *F. enigmaticus* when questioned, however the marina operators were concerned about potential spread.

In contrast with clear negative socioeconomic impacts exhibited by *F. enigmaticus*, it may have a beneficial effect on water quality in enclosed areas. Studies have demonstrated that large populations can reduce suspended particulate matter and improve oxygen load and nutrient status via filter feeding (Keene, 1980; Davies et al.1989). It is advisable that marina operators are informed about the potential impacts of the tubeworm, so that it can be readily identified and eradicated before large populations become established. Similarly, marinas already occupied by the worm should take steps to control or eradicate the population, for instance via flushing lock gates.

Bugulina simplex was recorded for the first time in the North West during this study in Fleetwood marina, with the nearest previous record in Victoria Dock in Wales (Wood et al., 2015). This is could be a recent range expansion; however alternatively it could be due *B. simplex* being overlooked in previous surveys. The species is regarded as being under recorded in Western Europe generally, as it can be mistaken for morphologically similar bryozoans (Ryland et al. 2011). Little is known about the ecological effects of *B. simplex* on native fouling communities, although there is the potential for this species to outcompete native species in a similar way to other Bugulina species. No adverse impacts on the environment or economy have been reported however (Hagan, 2016).

Lastly, it is worth noting that no INNS new to the UK were detected during the RAS 2016.

4.3 Settlement panels

Although panels were recovered from three out of the four marinas, it is unfortunate that none were recovered from Maryport, which could have yielded information on whether *F. enigmaticus* was reproducing in the marina. The loss of panels from Maryport was probably due to the strong water currents flowing through the marina from the lock gates. In hindsight it would be prudent to attach the panels more securely using cable ties as opposed to nylon cord, as this would improve the likelihood of retrieval.

Tricellaria inopinata occupied the most space of any INNS recorded on all panels, accounting for a much larger percentage cover than other non-natives in both Liverpool and Fleetwood. This species has spread rapidly since its introduction to Europe in the early

1980s, with a dispersal rate of up to 190 km yr^{-1} by means of anthropogenic vectors, primarily thought to be vessel hulls (Cook et al, 2013). The proliferation of *T. inopinata* in marinas is almost certainly facilitated by its tolerance a wide range of salinities and temperatures. Earlier studies specified the lower limit of salinity tolerance at 26 ppt (Cook et al, 2013); however our surveys recorded *T. inopinata* growing readily in marinas with salinity as low as 20 ppt (Appendix VI). Unlike many other bryozoans, *T. inopinata* can reproduce year-round, and also has preference for colonising artificial structures almost exclusively (De Blauwe & Faasse, 2001). This combined with a very short larval phase which exhibits phototactic behaviour, facilitates *T. inopinata* to rapidly colonise all available substratum adjacent to an existing colony (Johnson et al. 2012).

F. enigmaticus was the dominant INNS on panels from Whitehaven, with mature individuals occupying space all panels that were retrieved. This demonstrates the potential for the tubeworm to aggressively colonise clean artificial surfaces in a short time period (eight weeks). Vessel berthed on pontoons already colonised by *F. enigmaticus* could therefore readily act as a vector to transport the tubeworm between marinas. For more discussion on the implications of *F. enigmaticus,* please refer to the RAS section above.

Other INNS recorded on panels represented a smaller proportion of cover on average. *Bugulina stolonifera* was found on all panels from Liverpool but with far less abundance than the more dominant *T. inopinata. Botrylloides diegensis* only occurred on one panel from Fleetwood in a single large colony, which reflected low abundance recorded during RAS. *Austrominius modestus* occurred on a single panel from both Fleetwood and Whitehaven; however the barnacles were still very small and consequently did not account for a large proportion of percentage cover overall.

The lower number of INNS recorded on panels (5 species) compared with RAS (13 species) is likely due to the limited time period the panels were submerged. At the time of deployment, it is probable that the species reproducing (at that particular time) colonised the panels first, and hence represented the observed assemblage. If repeated in future, it would be interesting to deploy panels in multiple series to observe whether this affect the assemblage. Additionally, leaving panels for longer time could allow observation of succession of dominant INNS within the fouling assemblage.

4.4 Public awareness

The majority of marina users said that they would not be able to identify INNS, and therefore would not know to report them if observed. It would be beneficial for reporting if promotional materials with photographs (such as posters or leaflets) for identification of priority invasive species were displayed throughout marinas. These should contain contact information of how the public can to report sightings via email (i.e. local IFCA or Natural England).

5. Conclusions

This study has shown that within just one year there has been an increase in the frequency of INNS with a 17% increase in site occupancy since 2015. Compared to the rest of England the INNS assemblage in the North West is less speciose (Wood et al., 2016); however this is likely to increase year on year as the growth of maritime traffic facilitates the spread of species already established in the UK even further. Likewise, rising global seawater temperatures are predicted to accommodate the northward expansion of INNS that are currently at the lower limit of their thermal tolerance (Stachowicz *et al.,* 2002). Monitoring of marinas with RAS as often as reasonably practicable would be advisable to provide up-to-date records of INNS range expansion. Furthermore, it would be prudent for marinas to reduce the spread of economically detrimental species such as *F. enigmaticus* by taking reasonable precautions such as regular flushing of lock gates to reduce larval retention. Finally, it would be prudent to provide educational materials for marina operators and users (such as posters), so that they can recognise priority risk INNS and report sightings to the authorities.

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Appendices

Appendix I: Marine Strategy Framework Directive

The Marine Strategy Framework Directive (MSFD) was introduced in 2008 by the European Union to promote sustainable use of Europe's seas and conserve marine ecosystems. Its objective is to 'protect, preserve and improve the environment for present and future generations'. The main goal of the directive is to achieve Good Environmental Status in Europe's seas by 2020. The directive defines Good Environmental Status as "marine waters that provide ecologically diverse and dynamic oceans and seas which are clean, healthy and productive". There are 11 descriptors to guide evaluation of Good Environmental Status. Descriptor 2 is for Non-indigenous species – levels to be minimised.

MSFD is a cyclical process with each cycle taking 6 years. It requires EU countries to develop marine strategies following a specific timeline. The process follows a logical sequence of looking at the current state of the marine environment and setting targets, developing monitoring to measure progress against the targets, identifying measures that are needed to achieve the targets and then ongoing monitoring, evaluation and adaptation. For the first step, EU countries must carry out an initial assessment of the marine environment and define what 'Good Environmental Status' looks like for them. This includes setting targets and indicators, making Good Environmental Status something that can be measured.

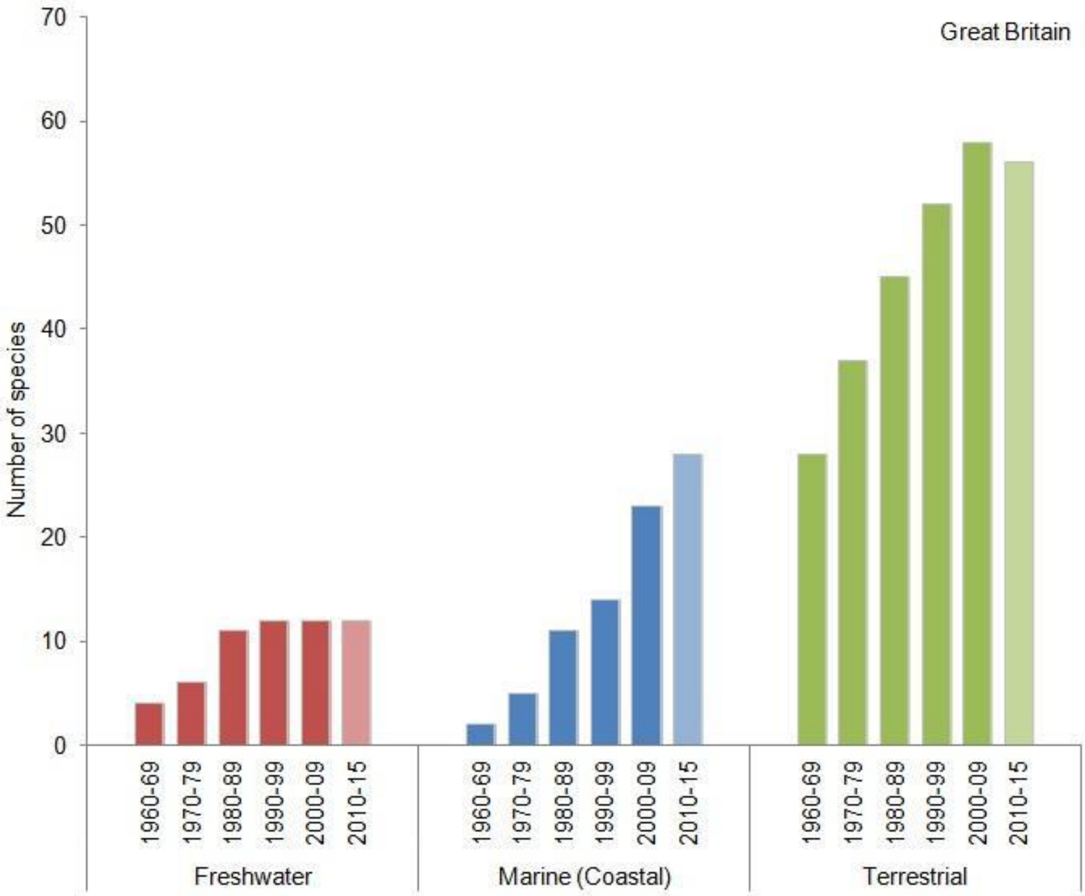
MSFD divides Europe's seas into regions and sub-regions. Within a sub-region the countries included are required to coordinate the development of their marine strategies.

(Reproduced from Wood et al., 2016, Information taken from the Celtic Seas Partnership website: http://celticseaspartnership.eu/background)

Appendix II: UK Biodiversity Indicators

The United Kingdom is a signatory to the Convention on Biological Diversity (CBD) and is committed to the biodiversity goals and targets ('the Aichi targets') agreed in 2010 and set out in the Strategic Plan for Biodiversity 2011-2020. The UK is also committed to developing and using a set of indicators to report on progress towards meeting these international goals and targets. There are related commitments on biodiversity made by the European Union, and the UK indicators may also be used to assess progress with these**.** The indicators are useful tools for summarising and communicating broad trends.

Indicator B6 description - Pressure from invasive species



The figure shows the change in number of invasive non-native species established across more than 10 per cent of the land area of GB, or more than 10 per cent of the extent of the coastline. There are 180 established invasive non-native species included within the indicator, comprising 39 freshwater species, 34 marine species and 107 terrestrial species. For the latest period 2010–2015, compared with 2000–2009, the number of these established in or along more than 10 per cent of Great Britain's land area or coastline has increased for freshwater species, to 14 from 13 and for marine species, to 27 from 23. Terrestrial species have decreased to 56 from 67. The short-term trend is not assessed.

(Reproduced from Wood et al., 2016, Information taken from http://jncc.defra.gov.uk/page-4229 (Crown copyright))

Appendix III: Target list of 37 INNS (reproduced from Wood et al., 2016)

Invasive non-native species	Description	Level of Threat
Styela clava (Leathery sea squirt)	Solitary, stalked ascidian native to NW Pacific. First recorded in UK 1953 in Plymouth Sound, Devon. Widespread in the UK for some decades.	Detrimental to aquaculture in some world regions, but may increase biodiversity per unit area of substrate.
Asterocarpa humilis (Compass sea squirt)	Solitary ascidian native to S Hemisphere. First recorded in UK in 2009 in SW England.	Recently recognised, and spreading rapidly in England, potential fouler of aquaculture equipment, clumps could clog pipes, potential competitor for food and space with cultured bivalves. Now entering natural habitats.
Ciona robusta	Formerly referred to as *Ciona intestinalis* Type A. Solitary ascidian, very similar in appearance to native species *Ciona intestinalis*. Considered native to the NW Pacific. Currently known only from the SW coast, Newlyn to Torquay.	Recently distinguished; threat to biodiversity – 'cryptic' species, potentially hybridises with native *Ciona intestinalis*; fouler of aquaculture equipment; competes for food with farmed species such as mussels and oysters.
Corella eumyota (Orange-tipped sea squirt)	Solitary ascidian, widespread throughout cooler waters of southern hemisphere. First recorded in the UK on the S coast in 2004. Now present throughout the UK.	Widespread in UK, forms large clumps, potential fouler of aquaculture equipment; entering natural habitats.
Botrylloides violaceus (Orange cloak sea squirt)	Colonial ascidian native to NW Pacific. Grows on hard artificial substrates as well as mussels, solitary ascidians and algae. First recorded in UK 2004 on the SW English coast.	Widespread in UK, threat to biodiversity and aquaculture through smothering, could block inlet pipes; entering natural habitats.

Botrylloides diegensis (San Diego sea squirt)	Colonial ascidian native to the W coast of N America. First recorded in UK in 2004 on the S English coast.	Spreading in England, threat to aquaculture through smothering.
Botrylloides sp. X	Colonial ascidian, origin and identity unknown.	Recently distinguished. Effects unknown.
Didemnum vexillum (Carpet sea squirt)	A colonial ascidian thought to be native to NW Pacific region. First recorded in UK 2008 in Holyhead Marina.	Local threat to biodiversity and local aquaculture through smothering. Thought to be a high impact invasive due to its rapid fouling abilities.
Perophora japonica (Creeping sea squirt)	A colonial ascidian of NE Asian origin, first recorded in Plymouth in 1999. Until recently only recorded from a limited number of sites in SW and S England, although widespread in France, however it has recently appeared in a number of natural habitats in estuaries and on the shore around the UK. A record from Milford Haven in 2002, included on various Web sites, was based on a misidentification.	Starting to appear in natural habitats e.g. off Norfolk coast; Salcombe estuary, Devon; Helford estuary, Cornwall; Strangford Lough, N Ireland.
Aplidium cf. glabrum	A colonial ascidian, similar in zooidal morphology to native Aplidium glabrum, but found in warmer waters than are typical of the native species. Origin and identity unknown.	Widespread in UK, threat to biodiversity and aquaculture through smothering, could block inlet pipes; entering natural habitats.
Tricellaria inopinata (Tufty-buff bryozoan)	An erect bryozoan native to temperate Pacific. Capable of enduring a wide spectrum of temperatures and salinities, as well as high organic content. Settles on a wide range of anthropogenic and natural substrata. First recorded in UK 1998 on S English coast.	Widespread in UK. Fouling nuisance and can affect biodiversity; entering natural habitats.

Bugula neritina *(Ruby bryozoan)*	A purplish-brown bryozoan that forms erect, bushy growths. Present from SW Scotland around Welsh and English coasts to Lowestoft. First recorded in c.1911 but by late 1990s was thought to be no longer present, but a rapid recolonization has since occurred.	Widespread in UK, can affect biodiversity. An abundant fouling organism that colonies a variety of sub-tidal substrata including artificial structures and vessel hulls.
Bugulina simplex	Previously called Bugula simplex. Erect straw-coloured bryozoan that forms funnel-shaped colonies. Thought to be native to eastern seaboard of N America or the Mediterranean. Until recently there were few UK records.	Effect unknown.
Bugulina stolonifera	Previously called Bugula stolonifera. Greyish-buff erect bryozoan which forms short compact tufts. Native to the Atlantic and Mediterranean. Until recently only known from S Wales and a few isolated English sites.	Effect unknown.
Watersipora subatra *(Red ripple bryozoan)*	Previously referred to as Watersipora subtorquata. An orange/red encrusting bryozoan from the S Hemisphere. Occurring from the lower intertidal to shallow sub-tidal. First recorded in Plymouth in 2008, it is now known from Plymouth to Poole Harbour, and in France from Brittany and Bordeaux.	Tolerant to copper based antifoulants. Spreading rapidly in England. It is highly invasive and has become common on coastlines throughout global cool-temperate waters since the 1980s.
Schizoporella japonica *(Orange ripple bryozoan)*	A bright orange encrusting bryozoan native to the N Pacific. Recorded in Holyhead marina in 2010, only other UK records are from	Recently recognised as an invasive species. Can form encrustations on ships, piers, buoys and other man-made structures in harbours

	Scotland and Plymouth.	and marinas. May compete for space with native species and S. japonica is known to inhibit the growth of adjacent species.
Diadumene lineata *(Orange-striped anemone)*	Small orange-striped anemone, native to Pacific. Probably introduced from Japan into the Atlantic towards the end of the 19th century. Distributed around Britain and throughout continental Europe	Effect unknown.
Austrominius modestus *(Darwin's barnacle)*	Four-plated barnacle native to Australasia, first recorded in UK in 1946.	Widespread throughout UK, competes for space with native barnacles. This species has largely displaced other barnacles in estuaries in SW Britain although impacts are less significant on exposed rocky shores.
Amphibalanus amphitrite *(Striped barnacle)*	Species of acorn barnacle native to SW Pacific and Indian Oceans. First recorded in UK in 1937 in Shoreham Harbour, Sussex. Populations have been found in S England and S Wales, initially associated with artificially warmed sites.	Now occurring on S coast of England. Can be a fouling nuisance on yacht hulls and equipment.
Amphibalanus improvisus *(Bay barnacle)*	Smooth, white or pale grey, 6-plated barnacle with a cosmopolitan distribution. First recorded in the UK by Darwin in 1854. Tolerant of brackish waters.	May dominate and outcompete native species, especially for available habitat. It can be a nuisance through fouling of ships' hulls, water inlet pipes, aquaculture products and equipment and other submerged structures.
Hesperibalanus fallax	Previously called *Solidobalanus fallax*. Small 6-plated barnacle with calcareous base, typically epibiotic. Plates white with reddish-	Effect unknown.

	purple patches. Native to tropical Atlantic coast of Africa. Rare along southwest coasts of England and Wales but becoming more frequent. First UK record 1994.	
Caprella mutica *(Japanese skeleton shrimp)*	Amphipod native to NE Asia. First recorded in the UK in 2000 from a salmon farm in Oban, Scotland.	Widespread, serious threat to native skeleton shrimp populations even at low densities. On the west coast of Scotland, their abundance can reach 300,000 individuals m -2. It has the potential for significant impacts on benthic communities.
Ammothea hilgendorfi *(Japanese sea spider)*	Pycnogonid native to N Pacific. Thought to be introduced as hull fouling from Japan. First recorded in the UK in Southampton Water in 1978	Preys on hydroids and anemones.
Crepidula fornicata *(Slipper limpet)*	Medium sized gastropod native to E coast of the Americas from Canada and Mexico. British population was introduced in 1890 in association with imported oysters	Habitat alteration, threat to biodiversity and aquaculture. Now a pest in commercial oyster beds.
Urosalpinx cinerea *(American oyster drill)*	A gastropod native to E coast USA. First recorded in Essex oyster grounds in 1927. It became widely distributed across Essex and Kent coasts, but there are few recent records.	Threat to aquaculture through feeding on bivalves. It is a major pest to the commercial oyster industry preying heavily on both native and introduced oyster species. It feeds preferentially on oyster spat and has been reported to decimate stocks of oyster spat in some estuaries.
Crassostrea gigas	A bivalve mollusc with thick, rough shells.	Displacement of native oysters; reef formation

(Pacific oyster)	Occurs naturally in Japan and SE Asia. First introduced from Portugal (as *C. angulata*) into the River Blackwater, Essex, in 1926. Re-introduced in 1965 to Conwy, North Wales (MAFF quarantine) from the USA and British Columbia.	leading to habitat alteration.
Ficopomatus enigmaticus *(Trumpet tube worm)*	A tube worm of unknown origin. Occurs in warm and temperate regions of both S and N hemispheres. Originally observed in London Docks in 1922 it favours coastal brackish waters.	Aggregations can change the geomorphology of the local ecosystem by altering hydrodynamic and sediment characteristics, and provide complex habitat for benthic species. May enhance water quality by removing particulate matter, but also reported to increase eutrophication in some instances. The tubes can be a fouling nuisance and block pipes.
Hydroides ezoensis	A tube worm thought to originate from Japan, indigenous to NW Pacific. First recorded in UK from Southampton Water in 1976.	Aggregations can be a nuisance, fouling harbour structures and ships' hulls. May provide habitat for free-living and sessile invertebrates.
Hemigrapsus spp. *(Asian shore and brush-clawed crabs)*	Small crabs native to the NW Pacific. Occur on muddy and rocky shores and in sheltered estuaries and port area. First UK records 2014, *Hemigrapsus takanoi* (brush-clawed crab) from R. Medway and Brightlingsea; *H. sanguineus* (Asian shore crab) from Wales and Kent.	Threat to biodiversity as they compete with native shore crab *Carcinus maenas*.
Undaria pinnatifida *(Wakame)*	Large brown alga indigenous to temperate regions of Japan, China and Korea. Grows on	Competes for space with native kelp species. May be a nuisance fouling jetties, vessels,

	hard substrates from low intertidal to approx. 18 m. Tolerant of salinities as low as 20. First recorded in UK June 1994 in the Solent	moorings and buoys.
Sargassum muticum *(Wireweed)*	Large brown alga indigenous to Japan and NW Pacific. Grows on hard substrates in shallow water down to approx. 5 m. First recorded in UK 1971 in Isle of Wight.	Overtops and shades native seaweeds. Fouling hazard to yachts.
Grateloupia turuturu *(Devil's tongue weed)*	Large red alga found growing on hard substrates down to 2 m below low water mark. Native to Pacific, probably Japan. Probably introduced to UK by spores travelling in ballast water. First recorded at Southsea beach in the Solent, in 1969.	Threat to native red algae, the large, broad blades may shade neighbouring species.
Codium fragile fragile *(Green sea fingers)*	Green seaweed with spongy finger-like branches. Native to the Pacific Ocean: Japan and Korea. In GB it was first recorded from the Yealm Estuary, Devon in 1939, growing on oyster shells.	Has the potential to compete with native species for space, forming dense assemblages and potentially altering community structure. A nuisance to fisheries and aquaculture, particularly on NW Atlantic shores, it fouls nets and may attach to, up-lift and move commercially produced shellfish and seaweed.
Colpomenia peregrina *(Oyster thief)*	Brown alga forming inflated thin-walled hollow spheres. Native to the Pacific Ocean. Introduced to Cornwall and Dorset from France in 1907.	May smother native species; can attach to oysters, become air-filled and buoyant then float away with the animal.

Chrysymenia wrightii *(Golden membrane weed)*	Large, glistening red seaweed. Indigenous to Japan. First UK record from Falmouth in 2013.	Effects unknown.
Caulacanthus okamurae (Pom-pom weed)	Small red seaweed forming dense springy clumps. Native to Asia. First UK record 2004 on S coast.	Turf formation can alter habitat displacing macro invertebrates, such as barnacles.
Bonnemaisonia hamifera (Hook weed)	Purplish-pink seaweed with delicate feathery fronds with curved hooks. Native to NW Pacific. Earliest UK record 1893 from Falmouth, now widespread.	It may become the dominant alga competing with other algae and seagrasses.

Appendix IV: Occurrence of fouling INNS at 4 sites on the North West English coast in 2015 and 2016

Table 2: Occurrence of fouling INNS at 4 sites on the North West English coast in 2015 and 2016. Notes: Abundance scores: Adapted and abbreviated SACFORN scale: 3 = Abundant/Superabundant, 2 = Frequent/Common, 1 = Rare/Occasional, Blank = Not present or not observed

		ASCIDIANS										BRYOZOANS						CNIDARIA	ARTHROPODS							MOLLUSCS			POLYCHAETES		ALGAE								
YEAR	SITE CODE	*Styela clava*	*Astercocarpa humilis*	*Ciona robusta*	*Corella eumyota*	*Botrylloides violaceus*	*Botrylloides diegensis*	*Botrylloides species X*	*Didemnum vexillum*	*Perophora japonica*	*Aplidium cf. glabrum*	*Tricellaria inopinata*	*Bugula neritina*	*Bugulina simplex*	*Bugulina stolonifera*	*Watersipora subatra*	*Schizoporella japonica*	*Diadumene lineata*	*Austrominius modestus*	*Amphibalanus amphitrite*	*Amphibalanus improvisus*	*Hesperibalanus fallax*	*Caprella mutica*	*Ammothea hilgendorfi*	*Hemigrapsus spp.*	*Urosalpinx cinerea*	*Crassostrea gigas*	*Crepidula fornicata*	*Ficopomatus enigmaticus*	*Hydroides ezoensis*	*Undaria pinnatifida*	*Sargassum muticum*	*Grateloupia turuturu*	*Codium fragile fragile*	*Colpomenia peregrina*	*Chrysymenia wrightii*	*Bonnemaisonia hamifera*	*Caulacanthus okamurae*	**TOTAL INNS**
2016	Mary	1			1														2										1										**4**
	White																		2		1								3										**3**
	Fleet	3			1	2	1				1	3		1	1				2												2			1					**11**
	Liv	3										2			2																								**3**
2015	Mary	1			1														2																				**3**
	White																		2		1								3										**3**
	Fleet	3			1	2	1				1	3							1												1			1					**9**
	Liv	3										2			2																								**3**

Appendix V: Public awareness questionnaire

Table 3: Questionnaire used to ask five marina users about their awareness of INNS, sightings reporting, and spread control (n = 5)

1	Are you aware of any invasive non-native species in marinas?	Yes = 60% No = 40%
2	Do you think INNS could be a problem?	Yes = 60% No = 20% Don't know = 20%
3	Could you recognise any INNS? If so, which species?	Tubeworm (*Ficopotamus enigmaticus*) only = 40% None = 60%
4	If you did observe INNS, would you report it?	Yes = 100%
5	How would you like to report sightings: A) An app B) Email an authority C) "owning" a panel	Email = 80% App = 20%
6	Have you heard of "Check-clean-dry" procedure to prevent spreading INNS? Would you/do you practise this procedure?	No, but practise this anyway = 80% Yes = 20%

Appendix VI: Environmental conditions

Table 4: Marinas surveyed with abiotic measurements

Abiotic measurement	Whitehaven	Maryport	Fleetwood	Liverpool
Temperature at 0 m (◦C)	17	17	19	19
Temperature at 2 m (◦C)	18	17	18	19
Salinity (ppt)	20	29	23	20
Secchi depth (m)	1	0.97	2.38	3.41