Natural England Commissioned Report NECR223

Investigating the Impacts of Marine Invasive Non-Native Species

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Foreword

Natural England commission a range of reports from external contractors to provide evidence and advice to assist us in delivering our duties. The views in this report are those of the authors and do not necessarily represent those of Natural England.

Background

Non-native species can become invasive, altering local ecology and out-competing native species. However, we currently lack evidence on the impacts that some of these species have on the environment, in particular to features of Marine Protected Areas and how best to incorporate the presence and potential impacts caused by invasive non-native species (INNS) in the assessment of site condition.

The Improvement Programme for England's Natura 2000 sites (IPENS) identified INNS as a key issue impacting our Natura 2000 sites. The theme plan of key actions includes gathering evidence on impacts to encourage uptake of best practice and also gathering evidence to help determine priority species to address.

The aims of this project were to carry out a literature review and gather evidence from stakeholders on the environmental (with a particular focus on MPA features) and socioeconomic impacts of 8 key marine INNS.

This report provides a useful reference source for information about both the economic and environmental impacts of 8 marine INNS which will help feed into improvements in our advice to operators on the potential impacts of invasive species, in turn helping us to encourage the uptake of mitigation and best practice to reduce the introduction and spread of these species. For example, new information previously unpublished and gathered from stakeholders includes anecdotal evidence of economic impacts from the trumpet tube worm *F. enigmaticus* and the leathery sea-squirt *S. clava*.

The focus of this report to provide evidence on potential susceptibility of MPA features in particular and the generation of a matrix tool which can be adapted in future to incorporate more species and new information will provide our staff and others with overview of potential risks and priorities. This information will feed into the guidance being developed on the condition assessment process as it will help staff to assess the potential threats of invasive species on the MPA.

Finally, the information gathered in this report will be provided to the GB Non Native Species Secretariat to input into risk assessments currently being written or not yet started for these 8 species. The recommendation to review the risk assessment process to include specific impacts to MPAs will also be taken forward for consideration.

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INVESTIGATING THE IMPACTS OF MARINE INVASIVE NON-NATIVE SPECIES

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The input of all the people who spent the time to respond to the survey is greatly appreciated. Their valuable contribution to the data gathering exercise provided a level of colloquial and 'hands-on' experience of non-native species that was essential and allowed recommendations to be presented that are founded within a 'real world' context.

The authors would also like to thank all the individuals who granted us permission to use their images of the various non-native species within this report.

Summary

Eight Non-Native Species (NNS), whose environmental and socio-economic impacts in the UK were poorly understood, or those with risk assessments by GB Non-Native Species Secretariat which had not been reviewed recently, were selected for investigation to assess their potential impacts on Marine Protected Areas (MPAs) in England and Wales. The eight species were:

- *Undaria pinnatifida*; Asian kelp
- *Ficopomatus enigmaticus*; Trumpet tube worm
- *Schizoporella japonica;* Orange ripple bryozoan
- *Sargassum muticum*; Wire weed
- *Hemigrapsus sanguineus*; Asian shore crab
- *Styela clava*; Leathery sea squirt
- *Corella eumyota*; Orange-tipped sea squirt
- *Grateloupia turuturu*; Devil's tongue weed

Information was gathered on the biology, habitat, ecology and socio-economic impacts of each NNS via a literature review and a stakeholder consultation survey. The survey was designed to acquire more colloquial experience of stakeholders, with respect to the eight NNS, that may not have been captured or documented within the literature sources.

All eight target NNS were found in one or more MPAs in England and Wales, and there were 209 records of one or more of these NNS in MPAs. Observed changes in MPA features were only reported for three of the target NNS including; *U. pinnatifida, Sargassum muticum*, and *C. eumyota*, whose introduction had led to changes in community composition. In addition, evidence suggested that a number of the eight target NNS could potentially cause changes to community structure on certain MPA intertidal and subtidal biogenic features. These features included biogenic reefs (e.g. mussel and *Sabellaria* spp.), subtidal macrophyte-dominated sediment, seagrass beds and native oysters (*Ostrea edulis*).

A matrix tool was created to prioritise the MPAs, which required more detailed risk assessment. This tool used a 'traffic light' system based on MPAs features, which were (i) susceptible to (or already colonised by) and (ii) were identified as likely to have one or more of the eight target NNS become established (see Supplementary Material). Sixteen of the 112 MPAs assessed were highlighted as 'red' under this system, in that they contained five or more suitable features and environmental conditions for the establishment by one or more of the eight NNS. Whereas, 25 MPAs were considered as 'green', in that the designated features of the site were not suitable for establishment by any of the eight target NNS. Two MPAs, Morecambe Bay SAC and the Exe Estuary SPA, were found to have five or more features (i.e. 'red'), susceptible to colonisation by the greatest number of the target NNS (5 out of 8) in this report. Morecambe Bay SPA, Plymouth Sound and Estuaries SAC and Fal and Helford SAC, were also listed as 'red' for 4 out of 8 of the target NNS.

It must be stressed, that a number of assumptions were made when developing the matrix tool, which can be refined over time as more environmental and monitoring data for specific sites becomes available. It is recommended that further evidence is gathered to help determine the point at which a particular NNS may start to have a detrimental impact on a particular feature. For example, at what density a NNS may become an issue. This will help inform both priorities for any

potential management and identify when features are likely to move into unfavourable condition. In the meantime, authorities and SNCBs will need to continue to make a judgement about the above based on the information provided in this report and other literature sources.

Finally, assessors should also be aware of the potential socio-economic impacts associated with specific NNS when preparing a risk assessment for a particular location and discussing biosecurity plans with relevant stakeholders. From the survey, the trumpet tube-worm *F. enigmaticus* and the leathery sea-squirt *S. clava* were both highlighted as causing fouling problems leading to loss of earnings for marina operators and the aquaculture industry, respectively.

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Acronyms & Abbreviations

CABI	Centre for Agriculture and Bioscience International
GB NNSS	GB Non-Native Species Secretariat
GIS	Geographical Information Systems
IPENS	Improvement Programme for England's Natura 2000 Sites
JNCC	Joint Nature Conservation Committee
MBA	Marine Biological Association, UK
MCZ	Marine Conservation Zone
MPA	Marine Protected Area
NBN	National Biodiversity Network
NIMPIS	National Introduced Marine Pest Information System (Australia)
NORSAS	North Sea Alien Species Database
NNS	Non-Native Species
NRW	Natural Resources Wales
SAC	Special Area of Conservation
SAMS	Scottish Association for Marine Science
SCI	Site of Community Importance
SNCB	Statutory Nature Conservation Body
SPA	Special Protection Area
SRSL	SAMS Research Services Ltd.

1 Introduction

Project background

1.1 Biological invasions by invasive Non-Native Species (NNS) are generally accepted to be one of the greatest threats to biodiversity world-wide (CBD, 1992). These species can cause huge economic and social impacts, and marine NNS are estimated to have direct cost to marine industries in Great Britain of approximately £40 million per year (Williams *et al*., 2010).

1.2 Ninety non-native species have been identified from British marine and brackish environments and 58 of these have become established (Minchin *et al*., 2013). A number of these species have either been, or are in the process of being, risk assessed through the work of the GB Non-Native Species Secretariat (GB NNSS). These risk assessments are based on the likelihood of entry, establishment, spread and potential level of impact.

1.3 Two species assessed as high risk include the slipper limpet *Crepidula fornicata* and the carpet sea squirt *Didemnum vexillum*. In the case of the former, there is considerable evidence to show that this species is having a significant economic impact on the mussel fisheries on the south coast of England (Syvret & Fitzgerald, 2008). Whilst the evidence of economic impacts for *D. vexillum* is substantial in other continents where it has become established, there have been no empirical studies to date showing that this species is having a deleterious impact on native species in the UK (Nimmo *et al*., 2012), particularly in Marine Protected Areas (MPAs). Unfortunately, however, existing impact data for the majority of marine NNS is scarce or based on anecdotal evidence (Ojaveer *et al*., 2015).

1.4 The Improvement Programme for England's Natura 2000 Sites (IPENS) and the Welsh LIFE N2K project identified NNS as a key issue impacting our Natura 2000 sites. Theme plans including key actions were developed as part of both projects which include gathering evidence on impacts to encourage uptake of best practice, biosecurity plans for MPAs and gathering evidence to help determine priority species to address (IPENS, 2012).

1.5 Recent reports (e.g. Stebbing *et al*., 2015; Pérez-Domínguez *et al.,* 2016) and work by the GB NNSS have highlighted that there are currently knowledge gaps and a lack of evidence concerning the impacts of NNS on marine habitats and species. Natural England and Natural Resources Wales (NRW) have revised their methods for assessing the condition of MPAs and are now reviewing how best to incorporate the presence of NNS within this process.

1.6 SAMS Research Services Ltd. (SRSL) was contracted by Natural England to undertake a review of the impacts of NNS, with a particular focus on MPA features. Six NNS were selected based on whether the evidence of environmental and socio-economic impacts is currently lacking or those with risk assessments by GB Non-Native Species Secretariat which had not been reviewed recently but which are commonly encountered and therefore further evidence would be beneficial. Additional funding was supplied by NRW to extend the list of species under investigation by two, resulting in a total of eight NNS to be reviewed. These eight target species are listed in Table 1 below.

Table 1. *List of NNS under investigation for this review. Species names correct according to WoRMS (2015)*

Species Name	Common Name(s)
Undaria pinnatifida	Asian kelp; wakame
Ficopomatus enigmaticus	Trumpet tube worm
Schizoporella japonica	Orange rippled bryozoan
Sargassum muticum	Wire weed
Hemigrapsus sanguineus	Asian shore crab
Styela clava	Leathery sea squirt; clubbed tunicate; Asian tunicate
Corella eumyota	Orange-tipped sea squirt
Grateloupia turuturu	Devil's tongue weed; gracie; red menace; red tide

Document purpose

1.7 This report details the methodology and results from the investigation, documenting the information found from the review process, and summarising the main findings of the stakeholder engagements and consultation. The potential impacts identified for each NNS during the review and consultation have then been placed into the context of the marine MPAs of England and Wales (N2K sites only in Wales), highlighting areas for concern to help guide condition assessment and management of MPA features in the future for these species.

2 Methodology

2.1 A list of English MPAs was provided by Natural England at the commencement of the project, along with the features and sub-features for which they have been designated. A list of Welsh SACs and SPAs and their designated features was downloaded from the Joint Nature Conservation Committee (JNCC) website. The types of MPA under investigation included Marine Conservation Zones (MCZs) in England, Ramsar sites in England, Special Areas of Conservation (SACs) in England and Wales, Sites of Community Importance (SCIs) in England, and Special Protection Areas (SPAs) in England and Wales. For SPAs only the supporting habitat features were included for the purposes of this project. A full list of the MPAs under consideration for this project is given in Appendix A.

2.2 In order to gather as much information as was practically possible on the eight NNS under investigation, two data collection exercises were undertaken. The first was a literature review, which concentrated on looking at published literature and other written reports. The second was a stakeholder consultation, aimed at gathering colloquial evidence that is typically not captured within formally recorded reports and papers. The methodologies for both these data collection exercises are further detailed below.

Literature review

2.3 To gather evidence on the impacts, particularly on MPA features, by the eight target NNS relevant information was identified and collated by undertaking a thorough literature search for published and grey data via web searches and personal recommendations. The latter included email and phone contact with national and international experts. Confidence assessment of literature sources was made, with greater weight placed on peer-review literature, but with the understanding that information on specific NNS could be sparse and, therefore, grey literature may have to be used.

2.4 Each of the eight NNS was described along with a summary of their biology, life history traits, environmental tolerances and known distribution. This information was used to draw up a matrix to show which particular features and sub-features present within the MPAs under study, were potentially susceptible to colonisation by one or more of the eight NNS.

Stakeholder consultation

2.5 In order to confirm and expand on the results of the literature review, a survey was created to collate information from key stakeholders on the potential ecological and socio-economic impacts associated with the eight NNS under investigation. The survey had two main aims:

- To gather information on the potential impacts to protected features within English and Welsh MPAs by the eight NNS.
- To collate any evidence of impacts by the eight NNS on industry and business, to better inform management decisions for all marine stakeholders.

2.6 A list of the key stakeholders to whom the survey would be sent was prepared in discussion with Natural England and NRW (Appendix B). This list included international and European experts, UK SNCBs, Regional Partnerships and industry stakeholders. The survey was conducted using SurveyMonkey, an online tool for designing and collating survey responses.

2.7 The identified stakeholders were emailed on the 6th October 2015 with a link to the survey and information detailing the survey objectives. To ensure that as much relevant information as possible was gathered, stakeholders were encouraged to circulate the survey link to any people they deemed appropriate, both within and outside their organisation. Through working in this way we aimed to reach as wide a geographically varied survey group as possible. Respondents were asked to provide contact details so that any responses could be followed up either by phone or email.

2.8 For each of the eight NNS, there was a set of principal questions related to the species interaction with MPAs, followed by questions relating to the economic impacts associated with that species. To avoid overburdening stakeholders with questions that they could not answer, individuals were asked a screening question ("Have you seen or had any experience with that particular non-native species?"), before being asked to provide more detailed information. A copy of the survey questionnaire can be found in Appendix C. After a review of the response trends, the survey was closed on 27th November 2015, as this was deemed a sufficiently long time period for all likely responders to complete the survey.

2.9 Survey responses were summarised for each species ensuring that as much of the information provided by respondents was captured. Where important new information was gathered respondents were contacted, typically by phone, to investigate and scrutinise the information further. The findings from this survey were compared to data from the National Biodiversity Network (NBN) Gateway database (NBN, 2015), which was last updated at the end of 2014 with respect to survey data. Recent reports from specific NNS surveys were also consulted to support findings.

3 Species Review

3.1 The data gathered from the literature review of each of the eight NNS is summarised below, including a species description, their biology, life history traits, environmental tolerances and known distribution. The specific information gathered from the consultation process for each of the eight NNS is also summarised. All eight target NNS were found in MPAs from England and Wales. **209 MPA records** of one or more of the target NNS have been summarised, followed by specific information on potential impacts to the ecology of particular MPAs, where information was given by the stakeholders. Finally, information gathered on socio-economic impacts associated with the eight NNS is summarised.

Undaria pinnatifida (Harvey) Suringar, 1873

Preferred Common Name

3.2 Asian kelp, wakame

Synonyms

3.3 *Alaria pinnatifida* Harvey, 1860; *Ulopteryx pinnatifida* (Harvey) Kjellman, 1885; *Alaria amplexicaulis* Martens, 1866

Domain

3.4 Eukaryota | Kingdom: Chromista | Phylum: Ochrophyta | Class: Phaeophyceae | Order: Laminariales

Description

3.5 Frond length of 1–3 m, spore producing stage of the lifecycle (i.e., sporophyte) has a pinnately-divided blade with distinct midrib, compressed stipe and fibrous holdfast. See Figures 1 and 2 for images of *U. pinnatifida*.

Native Range

3.6 North western Pacific shores; including Japan, Korea, northeast China and southeast Russia.

Invaded Range

3.7 Europe, North America, South America and Australasia. In Europe, this species is found in Belgium (Leliaert *et al*., 2000), France (Castric *et al*., 1993), Italy (Curiel *et* al., 2001), Spain (Salinas *et al*., 1996), Portugal, the Netherlands and the UK (Fletcher & Manfredi, 1995). Records for *U. pinnatifida* indicated that this species is particularly prevalent in the south coast of England, with records stretching north as far as Belfast, Isle of Man and Fleetwood on the west coast, and Grimsby on the east coast of England. From the survey, five respondents identified other non-MPA areas where *U. pinnatifida* had been observed, typically attached to marina pontoons. These additional areas were all consistent with current observation records for this species (NBN, 2015).

Figure 1. Basal stem of an *Undaria pinnatifida* plant © Adriaan Gittenberger/ GiMaRIS

Figure 2. Fully grown specimen of *Undaria pinnatifida* © Adriaan Gittenberger/ GiMaRIS

MPA distribution

3.8 *Undaria pinnatifida* has previously been recorded in **23 MPAs** in England and Wales, including nine designated SPAs, seven designated SACs, one designated SCI, and six designated and recommended MCZs (NBN, 2015). From the 24 respondents that had experience of *U. pinnatifida,* a total of five respondents identified four MPAs where this species had been observed. These included: Plymouth Sound and Estuaries SAC, Fal and Helford SAC, Thanet Coast SAC and Solent and Southampton Water SPA. This species has been previously recorded within all these MPAs (NBN, 2015).

Pathways of Spread

3.9 Hitch-hiking on other aquaculture species (e.g. oysters) or on vessel hulls (Forrest *et al*., 2000; Voisin *et al.*, 2005) is a commonly identified pathway of spread. Contamination of aquaculture equipment, buoys, ropes and fishing gear and secondary spread over short distances, via natural dispersal of spores, may also assist with dispersal (Farrell & Fletcher, 2006).

Habitat

3.10 *Undaria pinnatifida* grows on hard surfaces (i.e., rocks, artificial structures) from the lowest intertidal to a maximum subtidal depth of 18 m. This species is an annual alga, with the macroscopic sporophyll stage surviving less than 12 months. The sporophyll stage, however, can produce millions of spores which can survive up to 5 hours post spawning. The optimum growth period is when seawater temperatures are between 5–13 ºC (Saitoh *et al*., 1999). *Undaria pinnatifida* will however tolerate a wide range of temperatures and salinities, growing well in estuarine conditions (Farrell & Fletcher, 2000) and can survive adverse weather conditions by forming a dormant gametophyte. Salinities above 27 PSU however, are necessary for growth of the sporophytes and gametophyte development. Studies have suggested that the presence of the invasive clubbed tunicate, *Styela clava* may contribute to the establishment of *U. pinnatifida* in northern Patagonia, Argentina (Pereyra *et al*., 2015).

Ecological Impacts

3.11 *Undaria pinnatifida* is considered to be a highly invasive species (Gallardo, 2014). It has been shown to reduce native species diversity in some locations through competition with other macroalgal species, such as *Laminaria digitata* and *Saccharina latissima*, for both resources and through shading (Farrell & Fletcher, 2000; Valentine & Johnson, 2003; 2004; Hewitt *et al*., 2005). *Undaria pinnatifida* became the dominant fouling alga on the pontoons within a marina in Plymouth within a year of its first sighting (Minchin & Nunn, 2014). *Undaria pinnatifida* has become well established along intertidal and subtidal rocky substrata throughout the Plymouth Sound SAC (Heiser *et al*., 2014). *Undaria pinnatifida* is significantly more abundant on vertical substrata, were it can become the dominant macroalga in the same habitat as *Saccharina latissima* and *Saccorhiza polyschides* (Heiser *et al*., 2014). In the Netherlands, *U. pinnatifida* grows predominantly on the Pacific oyster (*Crassostrea gigas*) and mussels, however ecological impacts are yet to be observed (NORSAS, 2015). Those MPA features that have the potential to be colonised by *U. pinnatifida*, particularly in estuaries and low to moderate energy environments are summarised in Table 2.

Socio-Economic Impacts

3.12 *Undaria pinnatifida* has the potential to have an economic impact on aquaculture through its fouling ability, including increased labour and harvesting costs on fin- and shell-fish infrastructure, as equipment and boats require regular cleaning. Heavy infestations may also clog machinery and restrict water circulation (NIMPIS, 2015a).

3.13 No economic impacts directly relating to the presence and management of *U. pinnatifida* were reported in the survey. One respondent suggested that impacts relating to biofouling could be experienced. However, no data exists to quantify any potential impact.

MPA observations and additional information from the stakeholder survey

3.14 A number of respondents, largely from the Marine Biological Association of the UK (MBA), reported studying *U. pinnatifida* in the Plymouth Sound and Estuaries SAC. *Undaria pinnatifida* was first observed in the UK in the Hamble Estuary in 1994. Heiser *et al*. (2014) first observed the species off Plymouth in 2003, on artificial substrata. By the summer of 2011, *U. pinnatifida* had become well established along intertidal and subtidal rocky substrata throughout the Plymouth Sound SAC (Heiser *et al*., 2014).

3.15 The changes associated with the spread of *U. pinnatifida* throughout the Plymouth Sound SAC have been wide spread, with a time-scale in excess of 5 years. When respondents were asked whether they believed the conservation objectives of the MPA had been affected by the presence of this species, respondents highlighted the need for further research to study the effects of *U. pinnatifida* on natural populations, particularly with regards to whether the seasonal dominance of *U. pinnatifida* adversely affects other species.

3.16 One respondent reported observations of *U. pinnatifida* within the Fal and Helford SAC. This species was first recorded there in 2010 on artificial substrata (marina pontoons and boat hulls). Having originally been recorded as an isolated population, *U. pinnatifida* has since been recorded throughout the Fal estuary on marinas, pontoons and aquaculture structures. Observed changes included the potential competition with native species, but also the provision of habitat within holdfasts and blades. However, changes observed were not supported by field data and were restricted at present to artificial habitats. When respondents were asked whether they believe the conservation objectives of the MPA have been affected by the presence of this species, the respondent indicated that it was ‘too early to say’.

3.17 One respondent reported observations of *U. pinnatifida* within the Solent and Southampton Water SPA. *Undaria pinnatifida* was first recorded in this SPA in 2011 on artificial substrata (Old Royal Victoria pier). This is a recent addition with only a few individuals recorded and as a result, there have been no changes observed.

Ficopomatus enigmaticus (Fauvel, 1923)

Preferred Common Name

3.18 Trumpet tube worm

Synonyms

3.19 *Mercierella enigmatica* Fauvel, 1923

Domain

3.20 Eukaryota | Kingdom: Metazoa | Phylum: Annelida | Class: Polychaeta | Order: Sabellida

Description

3.21 *Ficopomatus enigmaticus* is a reef building polychaete, and is the only temperate water member of the *Ficopomatus* genus (ten Hove & Kupriyanova, 2009). The genus is characterised by a symmetrical body, operculum and collar chaetae which are coarsely serrated and simple in structure. The body length, without the tube is approximately 44 mm, but this can vary considerably among sites. The larvae typically settle on hard substrates, and in environments with calm conditions and shallow waters, *F. enigmaticus* can build individual reefs up to 7 m in diameter (Schwindt *et al*., 2004). Adjacent reefs have also been observed to coalesce with one another in a coastal lagoon in the SW Atlantic, forming platforms up to 12 m in length (CABI, 2015a). *Ficopomatus enigmaticus* is shown in Figures 3 and 4.

Figure 3. Close up of *Ficopomatus enigmaticus* tubes, showing flanges and flaring openings on some tubes © Leslie Harris, NHMLAC

Figure 4. *Ficopomatus enigmaticus* reefs in the Elkhorn Slough, California © Wasson 2001

Native Range

3.22 Unknown, potentially Australasia

Invaded Range

3.23 Europe, USA, Uruguay and Tunisia. In Europe, this species is found in Belgium, Bulgaria, Croatia, Denmark, France, Corsica, Germany, Greece, Ireland, Italy, the Netherlands, Portugal, Romania, Spain, Ukraine and the UK. In the UK, the species has been reported from Wales (Abereiddy, Dale, Milford Haven, Swansea and Cardiff), Northern England (Barrow-in Furness) and Southern England (Portishead, Porlock, Falmouth, Plymouth, Weymouth, Cowes, Southampton, Portsmouth, Emsworth, Chichester, Shoreham, Brighton, Dover, Ramsgate, Greenhithe and St. Helier) (Zibrowius & Thorp, 1989; Joyce *et al*., 2005). However, it is likely that due to the difficulties in identifying this species, the invaded range is likely to be greater. Records for *F. enigmaticus* indicate that this species can be found along the coasts of England and Wales from Whitehaven to the Humber. From the survey, three respondents identified non-MPA areas where *F. enigmaticus* had been observed, typically attached to marina pontoons (e.g. Swansea marina and Whitehaven marina). These records are all consistent with current observation records for this species (NBN, 2015).

MPA distribution

3.24 *Ficopomatus enigmaticus* has previously been recorded in **15 MPAs** in England and wales, including four designated SPAs, six designated SACs, one candidate SAC, one Ramsar site and three designated MCZs (NBN, 2015). From the 12 respondents that had experience of *F. enigmaticus,* no respondents identified MPAs where this species had been observed. However, one respondent indicated that it was present in Millbrook Lake, which drains into Plymouth Sound and Estuaries SAC and is controlled by a sluice gate. *Ficopomatus enigmaticus* was reported in Millbrook Lake in 1985, but was unconfirmed until 2011 when the Environment Agency drained the lake and samples were obtained.

Pathways for Spread

3.25 The most likely vectors for spread are hull fouling and ship ballast, either in the water or sediment (Zevina & Kunznetsova, 1965), and from aquaculture as a hitch-hiker during stock transfer (USGS, 2009). Natural dispersal of *F. enigmaticus* is predominantly driven by local currents, since the larval swimming ability is poor (<5 mm/s) (ten Hove & Kupriyanova, 2009).

Habitat

3.26 *Ficopomatus enigmaticus* typically inhabits brackish water environments (10–30 PSU optimum), particularly in sheltered regions such as estuaries, inland saline lagoons and inshore marine environments, such as ports and harbours, since the calcareous tubes protecting the polychaete can easily be damaged by wave action (Bianchi & Morri, 2001). *Ficopomatus enigmaticus* is commonly found in shallow waters at depths between 0.5 and 2 m, although it has been observed at a depth of 9 m in the Netherlands (Sluys *et al.,* 2005) and 40 m in Greece (Antoniadou & Chintiroglou, 2005). The larvae require a hard substratum for settlement, such as small stones, piers, vessel hulls, empty shells, anthropogenic debris (Schwindt & Iribarne, 2000), macroalgae and submerged trees (Fornós *et al*., 1997). The minimum water temperature required for successful reproduction in the UK (Emsworth lagoon) has been recorded as 10 ºC (Thorp, 1995), although 15–18 ºC appears to be the most favourable temperature range for reproduction (CABI, 2015a).

Ecological impacts

3.27 *Ficopomatus enigmaticus* has a high growth rate, high fecundity and high larval retention in semi-enclosed, brackish waters. It has a high tolerance to variable environmental conditions, such as temperature, oxygen, salinity, water turbidity and pollution. The presence of *F. enigmaticus* can lead to physico-chemical changes in the environment, including altering the hydrodynamic flow regime of an area, leading to increased sediment deposition, the development of anoxic sediments and the hyper-accumulation of nutrients and organic materials (Schwindt *et al*., 2004; Sorokin *et al*., 2004). The MPA features that have the potential to be colonised by *F. enigmaticus*, particularly in estuaries and low energy environments are summarised in Table 2.

Socio-Economic Impacts

3.28 *Ficopomatus enigmaticus* is known throughout its invaded range as a major fouling species on artificial structures. In New Zealand, a power station had to change to a freshwater cooling system after the water intake pipes became repeatedly obstructed by this species (Read & Gordon, 1991). *Ficopomatus enigmaticus* has also been recorded as affecting power station installations in other countries, such as the Netherlands (Sluys *et al.,* 2005), the USA (Hoagland & Turner, 1980), Denmark, Italy (Bianchi & Morri, 1996) and the UK (Markowski, 1960), although the economic cost of clearing these systems for this particular species is unknown. However, it has been estimated that the water and power producing industries in the UK spend approximately £10 million annually to prevent pipe blockages from NNS using a variety of mechanical and chemical methods (Williams *et al*., 2010).

3.29 From the survey a number of economic impacts were identified for *F. enigmaticus* where this species was causing a significant biofouling concern. Fouling associated with this species was particularly prevalent in the summer of 2013 in Whitehaven marina. Exposed surfaces such as propellers, shafts and hulls were all affected leading to reduced vessel speeds, increased fuel consumption and in some cases engine problems. To encourage boat owners to use Whitehaven marina despite the fouling problem, the marina offered a reduced berthing fee. Furthermore, one respondent reported that a large commercial vessel was sent to dry-dock to be cleaned. A mild winter was reported to be partly responsible for greater growth rates observed in this species. *Ficopomatus enigmaticus* is a temperate/warm temperate species, and is thought to be at the limit of its range for maintaining populations and sexual reproduction on the south coast of England (Zibrowius & Thorp, 1989). The biofouling problem associated with *F. enigmaticus* is ongoing, with similar complaints being reported from Swansea and Portishead marinas, in addition to another marina that wished to remain anonymous.

MPA observations and additional information from stakeholder survey

3.30 No respondents supplied additional information regarding the ecological impacts of *F. enigmaticus* within any MPA.

Schizoporella japonica Ortmann, 1890

Preferred Common Name

3.31 Orange ripple bryozoan

Synonyms

3.32 *Schizoporella unicornis* (Oka, 1929), *Schizoporella unicornis* var. *japonica* (Ortmann, 1890)

Domain

3.33 Eukaryota | Kingdom: Metazoa | Phylum: Bryozoa | Class: Gymnolaemata | Order: Cheilostomatida

Description

3.34 Whitish, pink or bright red/ orange in colouration, colonies can be extensive, covering square metres of substratum. Single layer, although can appear multi-layered due to overgrowth, zooids rectangular, with rounded far end and arranged in columns radiating out from centre of colony. Oral avicularia may be absent, single or paired on a given zooid right next to the opening or orifice, some colonies may also have larger, raised frontal avicularia. Perforations over entire frontal wall, operculum light golden brown and transparent. Raised conspicuous, globular ovicell with small pores over entire surface and heavy ribs converging towards the midline. *Schizoporella japonica* is a cold water species with a breeding season that extends through the winter months. Figures 5 and 6 show images of *S. japonica*.

3.35 *Schizoporella japonica* can be easily confused with the native bryozoans *S. unicornis* and *S. errata*, which are common fouling species in the UK. Perforations are only present around the edge of the ovicell and smaller openings are found in *S. unicornis* compared with *S. japonica*.

Native Range

3.36 North western Pacific

Invaded Range

3.37 Australia, New Zealand (Bock, 2015), Pacific coast of North America and the UK. In the UK, *S. japonica* was first recorded in Holyhead marina, North Wales in 2010 (Ryland *et al.,* 2014), and has since been observed in Orkney, north coast of Scotland (Ryland *et al.,* 2014), In England, *S. japonica* has been recorded in two marinas in the Plymouth area; where it was recorded as abundant (Wood et al., 2014, 2015). However, it likely that due to the difficulties in identifying this species that the invaded range is greater. Three respondents identified other non-MPA areas where *S. japonica* had been observed, typically attached to artificial structures (e.g. marinas, boat hulls and concrete surfaces). These areas were all consistent with current observation records for this species (NBN, 2015).

MPA distribution

3.38 The bryozoan *S. japonica* has not previously been recorded in any MPAs in England or Wales. However, *S. japonica* has been recorded in the Cromarty Firth SPA and the neighbouring Moray Firth SAC in Scotland (NBN, 2015). From the eight respondents which had experience of *S. japonica*, one respondent identified that the species had been recorded from the Plymouth Sound and Estuaries SAC. One respondent indicated that there was a risk of *S. japonica* being introduced to the Fowey Estuary (Upper Fowey and Pont Pill MCZ).

Figure 5. Orange ripple bryozoan *Schizoporella japonica* on mooring buoy © Jirina Stehlikova, SAMS

Figure 6. Orange ripple bryozoan *Schizoporella japonica* on blue mussel shell © Chris Nall, UHI

Pathway for Spread

3.39 Aquaculture via stock transfers and vessel movement, either through hull fouling or ballast water have been identified as likely pathways for spread (Ryland *et al.,* 2014).

Habitat

3.40 *Schizoporella japonica* attaches to natural and artificial hard substratum, rocks, shells and algae (Bock, 2015). In the UK, *S. japonica* has typically been found on intertidal and subtidal artificial structures (e.g. pontoon floats, fenders, tidal turbine, vessel hulls, mussels, algal holdfasts) and their associated epi-fouling biota (Nall *et al*, 2014; Ryland *et al*, 2014). *Schizoporella japonica* tolerates temperatures from 7–19 ºC and salinities from 18–34 PSU (Wood, 2014).

Ecological Impact

3.41 There are no known impacts recorded as yet for *S. japonica*; however, this species has been observed to overgrow other native epi-fouling species and form dense monocultures on artificial structures on the west coast of Scotland (E. Cook, pers. obs). It may also prevent other species from growing on surfaces where it has become established (Treibergs, 2012). *Schizoporella japonica* appears to proliferate in cold water conditions, thereby taking advantage of conditions when native species may be dormant (Ryland *et al*., 2014). Those MPA features that have the potential to be colonised by *S. japonica* particularly in low to moderate energy environments are summarised in Table 2.

Socio-Economic Impacts

3.42 *Schizoporella japonica* has the potential to overgrow bivalves and prevent their feeding (J. Loxton, pers. comm.), plus there are additional costs for cleaning stock and farm equipment, so there are potential cost implications for the aquaculture industry.

3.43 No economic impacts directly relating to the presence and management of *S. japonica* were reported by the survey respondents.

MPA observations and additional information from stakeholder survey

3.44 A number of respondents reported *S. japonica* in the Plymouth area; however, this record does not exist on the NBN website as being part of the Plymouth Sound and Estuaries SAC (NBN, 2015). The two marinas where this species was recorded in Plymouth occur just outside the Plymouth Sound and Estuaries SAC boundary (Wood *et al.,* 2014). The respondents from the MBA are monitoring the presence of this species closely. No records of *S. japonica* have been observed within the Plymouth Sound and Estuaries SAC to date.

Sargassum muticum (Yendo) Fensholt, 1955

Preferred Common Name

3.45 Wire weed

Synonyms

3.46 *Sargassum (Backrophycus) muticum* (Yendo) Fensholt, 1955, *Sargassum kjellmanianum f. muticum* Yendo, 1907

Domain

3.47 Eukaryota | Kingdom: Chromista | Phylum: Ochrophyta | Class: Phaeophyceae | Order: Fucales

Description

3.48 Large brown macroalga, with thallus up to 10 m in length (Riberia & Bourdouresque, 1995). Fibrous, circular holdfast up to 1.5 cm in diameter, supports a main axis which is typically solitary. Lateral branches are spirally arranged along the main axis to form an intricate, bushy thallus. The leaves have toothed margins and with no midrib, the vesicles (pneumatocysts) are spherical to obovoid. Plants are monoecious, although male and female reproductive organs are in separate conceptacles (CABI, 2015b). *Sargassum muticum* is shown in Figures 7 and 8.

Figure 7. *Sargassum muticum* collected from Mull of Kintyre © Elizabeth Cook, SAMS

Figure 8. *Sargassum muticum,* image showing the vesicles (pneumatocysts) © Elizabeth Cook, SAMS

Native Range

3.49 Japan, China and Korea

Invaded Range

3.50 Pacific and western coasts of North America, Canada, Alaska, Mexico and western coasts of Europe (CABI, 2015b). In Europe, *S. muticum* is distributed from southern Norway to Portugal and the Mediterranean Sea. In the UK, it has now spread from the south coast of England, where it was first recorded in 1973 (Farnham *et al*., 1973), to the northwest coast of Scotland (Harries *et al*., 2007). Eight survey respondents identified other areas where *S. muticum* had been observed, typically within rock pools, marinas and growing on subtidal substrata. These additional areas were all consistent with current observation records for this species (NBN, 2015).

MPA distribution

3.51 From the list of marine MPAs examined in this project, *S. muticum* has previously been recorded from **65 MPAs** in England and Wales, including 15 designated SPAs, 17 designated SACs, one candidate SAC, four SCIs, two Ramsar sites and 26 designated MCZs (NBN, 2015). Of the 36 respondents that had experience of *S. muticum*, a total of 21 respondents identified 11 MPAs where this species had been observed. *Sargassum muticum* has been previously recorded within all the MPAs highlighted by respondents, with the exception of the Cumbria Coast MCZ and the Morecambe Bay SAC (NBN, 2015). Records from Morecambe Bay were made in 2011 with *S. muticum* observed in Walney Channel growing on cobble and boulder substrate. Records from the Cumbrian coast observed *S. muticum* in rock pools high on the shore at Nethertown.

Pathway for Spread

3.52 Primary introductions of *S. muticum* have been linked to the stock movements of the Pacific oyster *Crassostrea gigas* for aquaculture purposes, both to the Pacific coast of North America (Scagel, 1956) and to Europe (Farnham, 1980), and via the entanglement of plants around submerged vessel structures (Critchley 1983) or attachment to vessel hulls (Abbott & Huisman, 2004). Once established, pathways for secondary spread included hull fouling (Harries *et al*., 2007) and natural dispersal of detached thalli, with estimated rates of spread ranging from 2-3 km per year in Ireland (Kraan, 2008), to 60 km per year in the northwest coast of America (Farnham *et al*., 1981). Once established in a new region, germlings from a fertile plant can help facilitate further spread, although their effective dispersal range is typically less than 5 m (Andrew & Viejo, 1998).

Habitat

3.53 *Sargassum muticum* is predominantly found in inshore marine environments, where it occurs from the intertidal zone, typically in rock pools as it has very limited tolerance to desiccation, down to a depth of 20 m (Riberia & Bourdouresque, 1995). *Sargassum muticum* has also been found to occur in estuaries and lagoons; however, it has been suggested that *S. muticum* will be unable to reproduce if salinity is consistently <15 PSU and may be unable to compete effectively if salinity is <25 PSU (Steen, 2004). It is generally found in sheltered locations protected from wave action (Engelen & Santos, 2009), where it prefers to attach to natural and artificial hard substratum, including boulders, stones, wood, mooring lines and harbour wharves (Curiel *et al*., 1998). Experimental evidence suggests that the optimal temperature for growth and reproduction is about 25 °C (Hales & Fletcher, 1989). However, reproduction can occur at 10 °C (Hales & Fletcher, 1989) and growth is possible at 5°C (Norton, 1977).

Ecological Impact

3.54 Significant habitat modification has resulted from the extensive colonisation of areas by *S. muticum*, leading to changes in resident infaunal communities (Strong *et al*., 2006). Studies on the impact of *S. muticum* on seagrass beds have been conflicting, but more recent investigations have found that this alga can become established in sea grass beds by colonising the sea grass matrix itself rather than the unsuitable underlying sandy substratum (Den Hartog *et al*., 1992; Kraan, 2008; Tweedley *et al*., 2008). Once established *S. muticum* may then interfere with seagrass regeneration, although this requires further investigation. In the subtidal, studies have indicated that *S. muticum* can significantly impact on native macroalgal assemblages through overgrowing and shading of the underlying species; including *Halidrys siliquosa*, *Laminaria*, *Fucus* and *Codium* species (Stæhr *et al*., 2000). *Sargassum muticum* has also been shown to impact on native sea urchins by reducing the abundance of their preferred food source (a native macroalga) (Britton-Simmons, 2004). Those MPA features have the potential to be colonised by *S. muticum*, particularly in low to moderate energy environments are summarised in Table 2.

Socio-Economic Impacts

3.55 *Sargassum muticum* can significantly impede both recreational and commercial use of waterways through the formation of large floating rafts (Engelen & Santos, 2009).

Sargassum muticum has been reported as blocking intake pipes for aquaculture facilities and fouling fishing gear, oyster ropes and boat propellers (Riberia & Bourdouresque, 1995; Kraan, 2008).

3.56 No economic impact directly relating to the presence and management of *S. muticum* was observed by respondents. One respondent indicated that Devon Wildlife Trust would like advice about removal of the species. Furthermore, *S. muticum* is listed in the Fowey Estuary Biosecurity Plan (currently in preparation), which may result in potential costs associated with control measures.

MPA observations and additional information from the stakeholder survey

3.57 Potential changes associated with the presence of *S. muticum* within the 13 MPAs identified by respondents are summarised together in Appendix D. *Sargassum muticum* was also reported in the Swale Estuary, which is a proposed MCZ. *Sargassum muticum* was first recorded within the Swale Estuary in 2013 on subtidal mixed sediment and is now widespread across the area.

Hemigrapsus sanguineus (De Haan, 1853)

Preferred Common Name

3.58 Asian shore crab

Synonyms

3.59 *Grapsus* (*Grapsus*) *sanguineus* De Haan, 1835, *Heterograpsus maculatus* H. Milne Edwards, 1853

Domain

3.60 Eukaryota | Kingdom: Metazoa | Phylum: Arthropoda | Class: Malacostraca | Order: Decapoda

Description

3.61 *Hemigrapsus sanguineus* has a squarish carapace, usually patterned and dark in colouration (brownish orange to greenish black), with three distinct ‘teeth’ at each side of the carapace (Figure 9). A distinct banding pattern is visible on the ‘walking’ legs. The adult size ranges from 35–40 mm in carapace width. *Hemigrapsus sanguineus* exhibits rapid growth, has a high reproductive potential (a single female can produce >50,000 eggs per spawning), is highly adaptable and gregarious. In the USA, *H. sanguineus* has been found at densities often 60-80 times greater than *Carcinus maenas* (European green crab, also an invader in this region).

Native Range

3.62 Western Pacific Ocean including China, Japan, Korea and Russia (22º N to 49º N) (Sakai, 1976).

Figure 9. Asian Shore Crab *Hemigrapsus sanguineus* © Fiona Crouch, MBA

Invaded Range

3.63 US, including New Jersey (Williams & McDermott, 1990) Maine, North Carolina and Europe, including France, Belgium, Germany, (Dauvin *et al.,* 2009) the Netherlands, Croatia and the UK. In the UK, *H. sanguineus* has been reported from South Wales (one individual) and Kent (three individuals) in 2014, and specimens have been reported in Jersey and Guernsey since 2000 (Sweet & Sewell, 2014).

3.64 Two survey respondents identified the area in South Wales (Aberthaw) where *H. sanguineus* had been recorded in 2014. This species was initially recorded as having a localised distribution on the rocky shore. A subsequent survey undertaken by Natural Resources Wales in the same area found no evidence of *H. sanguineus*. This record is consistent with current observation records for *H. sanguineus* (NBN, 2015).

MPA distribution

3.65 *Hemigrapsus sanguineus* has previously been recorded in **two MPAs** in England and Wales, including one designated SPA and one designated SAC (NBN, 2015). From the four respondents that had experience of *H. sanguineus*, none identified any MPAs where this species had been observed.

Pathway for Spread

3.66 Likely introduced accidentally with ballast water (larval phase) and ship hull fouling (adults) (Williams & McDermott, 1990). Natural larval dispersal is also possible for secondary spread.

Habitat

3.67 In native range, *H. sanguineus* is typically found along cobble/ boulder coastlines and estuarine environments. Salinity range tolerated is 25–35 PSU and temperatures 5–30 ºC. In the invaded range, *H. sanguineus* is generally found in intertidal rock pools (Lohrer & Whitlatch, 2002), intertidal and subtidal oyster reefs and on artificial structures such as jetties, bulkheads, wooden piers etc. It appears to be able to withstand conditions both on exposed coastlines and in sheltered harbours (Lohrer, 2001). Larvae can spend between 16–55 days in the water column prior to metamorphosis enabling long distance, natural dispersal (Sweet & Sewell, 2014).

Ecological Impact

3.68 Potential for *H. sanguineus* to out-compete the native European green crab *Carcinus maenas*, the juvenile stages of the edible crab *Cancer pagurus* (Sweet & Sewell, 2014), and have a negative impact on prey species, such as juvenile mussels (Lohrer, 2001). Wider impacts could potentially include modification of natural benthic communities and reduced native biodiversity. Those MPA features that have the potential to be colonised by *H. sanguineus*, from low to high energy environments are summarised in Table 2.

Socio-Economic Impacts

3.69 Potential indirect impact on the spat supply for the mussel and oyster farming industry, through predation on juvenile blue mussels (Sweet & Sewell, 2014).

3.70 No economic impacts directly relating to the presence and management of *H. sanguineus* were reported by the survey respondents.

MPA observations and additional information from the stakeholder survey

3.71 No survey respondents supplied any additional information referring to ecological impacts of *H. sanguineus* within any MPA.

Styela clava Herdman 1881

Preferred Common Name

3.72 Asian tunicate; leathery sea squirt, club tunicate

Synonyms

3.73 *Botryorchis clava* (Herdman, 1881); *Styela barnharti* Ritter & Forsyth, 1917; *Styela mammiculata* Carlisle, 1954; *Tethyum clava* (Herdman, 1881)

Domain

3.74 Eukaryota | Kingdom: Metazoa | Phylum: Chordata | Class: Ascidiacea | Order: Stolidobranchia

Description

3.75 Large, club-shaped solitary ascidian reaching a length of up to 160 mm. *Styela clava* has a tough, leathery, cylindrical tunic which is supported by a stalk of variable length. The coloration can vary from brownish-white to reddish-brown. The two short siphons each have a 4-lobed opening and are found on the top of the body. The tunic has conspicuous bumps and the stalk is highly creased. *Styela clava* can be seen in Figures 10 and 11.

Native Range

3.76 Pacific coast of Asia and Russia (Goldstien *et al*., 2010).

Invaded Range

3.77 Australia, New Zealand, Pacific and Atlantic coasts of North America, Brazil, Argentina and Europe, including the Mediterranean (Davis & Davis, 2007). In the UK, *S. clava* was first reported in Plymouth South in 1953 (Carlisle, 1954), and has since spread along the south and south-east coasts of England, the coasts of Wales and Northern Ireland and the west coast of Scotland. Records for *S. clava* indicated that this species is particularly prevalent in the south coast of England (NBN, 2015).

3.78 Seven survey respondents identified other non-MPA areas where this species had been observed, typically attached to marina pontoons and artificial substrate. These areas were all consistent with current observation records for this species (NBN, 2015).

MPA distribution

3.79 *Styela clava* has previously been recorded in **52 MPAs** in England and wales, including 17 designated SPAs, 15 designated SACs, one candidate SAC, four designated SCIs, two designated Ramsar sites, and 13 designated MCZs (NBN, 2015). Of the 21 respondents that had experience of *S. clava*, nine respondents identified six MPAs where this species had been observed. These included Fal and Helford SAC, Pembrokeshire Marine SAC, Lleyn Peninsula and the Sarnau SAC, Solent Maritime SAC, Start Point to Plymouth Sound and Eddystone SCI and Poole Harbour SPA. *Styela clava* has been previously recorded within all these MPAs (NBN, 2015). Records from Fowey Estuary were made during Seasearch dives and were made just outside the MCZ boundary.

Figure 10. The clubbed tunicate *Styela clava* © Christine Beveridge, SAMS

Figure 11. The clubbed tunicate *Styela clava* with associated epifauna © Christine Beveridge, SAMS

Pathway for Spread

3.80 Highly likely to be spread via fouled aquaculture and fishing equipment, via aquaculture stock transfers and hull fouling (Minchin *et al*., 2013).

Habitat

3.81 Typically found on sheltered coasts and embayments in upper sublittoral zone to a depth of approximately 25 m. *Styela clava* attaches to hard substratum, where it can reach densities of 500–1500 individuals per m^2. It has been found attached to rocks, wood, cement and concrete pontoons, vessel hulls, as well as other species (e.g. *Crassostrea gigas*, *Mytilus edulis* and *Sargassum muticum*) (Davis & Davis, 2007; Clarke & Therriault, 2007). *Styela clava* has become established in regions with annual water temperature ranges from -2 °C to 23 °C, and salinities of 22-36 PSU. Adults of *S. clava* die in salinities below 10 PSU, and larvae below 18 PSU, whilst the species breeds in water temperatures above 15 °C and salinities above 25-26 PSU (Clarke & Therriault, 2007).

Ecological Impact

3.82 *Styela clava* can reach extremely high densities and have serious negative impacts on native species through competition for space and food. *Styela clava* will also predate upon larvae of native species from the water column (NIMPIS, 2015b). Those MPA features that have the potential to be colonised by *S. clava*, particularly in low to moderate energy environments are summarised in Table 2.

Socio-economic impact

3.83 *Styela clava* can considerably increase the costs of producing rope-grown aquaculture species through the heavy fouling of lines. In Prince Edward Island, Canada, it has posed a severe threat to the long term economic viability of the shellfish industry. *Styela clava* can also increase the drag on vessel through hull fouling, requiring an increase in fuel costs and frequency of hull cleaning (NIMPIS, 2009b).

3.84 From the survey undertaken, one respondent highlighted an issue regarding the increased labour costs of removing *S. clava* from mussel lines. During a site visit, a mussel farmer demonstrated how lines are cleaned by passing the mussels through a brushing system. The technique easily removed native ascidians present at the site (e.g. *Ciona intestinalis*). However, tougher non-native ascidians such as the Compass Sea Squirt (*Asterocarpa humilis*) and *Styela clava* were not removed by the brushes, and thus had to be removed by hand. In addition to competing with stock, these species increased handling time and, therefore, increased associated labour costs. It is not clear to what extent *S. clava* impacts on the mussel growing industry in the UK at present.

MPA observations and additional information from stakeholder survey

3.85 Within the Fal and Helford SAC, *S. clava* has been observed on subtidal rock and artificial substrata. No changes were observed in the condition of this site in association with this species.

3.86 *Styela clava* has been recorded within the Pembrokeshire Marine SAC at numerous sites over the last 20 years, and was first observed in Westdale Bay in 1968 (NBN, 2015). *Styela clava* was observed on subtidal rock and intertidal pools in addition to artificial structures such as marinas, jetties and wrecks. No changes in site condition were observed in association with *S. clava*. The distribution of the species at this site was localised with low abundance across the area.

3.87 Localised patches (approximately 100 m) with low abundance were observed within the Lleyn Peninsula and the Sarnau SAC. *Styela clava* was observed growing on mixed substrata in sheltered areas. No changes were observed at this site with respect to association with this species. *Styela clava* had not grown to high abundances at this site, and blends into the native flora and fauna, often providing a raised substratum for epibiota to grow on.

3.88 *Styela clava* was distributed across Poole Harbour SPA within the seagrass bed in addition to the harbour and marina wall. *Styela clava* was observed growing on the NNS *Crepidula fornicata*. No changes were observed at this site in association with this species.

3.89 *Styela clava* was also observed in Solent Maritime SAC and Start Point to Plymouth Sound and Eddystone SCI attached to reefs, intertidal rock and artificial structures. No further information was given for these two sites.

3.90 No respondents believed that the presence of *S. clava* undermined the conservation objectives of the MPAs where the species had been recorded.

Corella eumyota Traustedt, 1882

Preferred Common Name

3.91 Orange-tipped sea squirt

Synonyms

3.92 *Corella benedeni* Beneden & Longchamps, 1913; *Corella dohrni* Beneden & Longchamps, 1913; *Corella novarae* Drasche, 1884

Domain

3.93 Eukaryota | Kingdom: Metazoa | Phylum: Chordata | Class: Ascidiacea | Order: Phlebobranchia

Description

3.94 Smooth, slightly translucent, typically 2-4 cm in length as an adult, but can grow up to 8 cm (El Nagar *et al.,* 2010). Generally lies flat against the substrate attached along its right-hand side. The inhalant siphon is typically at the far end of the body (i.e. the unattached end), and the exhalent siphon is between a quarter and half-way down the body, on the upper surface and slightly to the right. Siphons frequently have orange tinge, whilst some individuals can be entirely orange. The gut forms a smooth conspicuous curve around the hind end of the body. *Corella eumoyta* attaches to hard substrates and can be often found adhering tightly to one another in groups. *Corella eumyota* can be seen in Figure 12.

Figure 12. *Corella eumyota* © Chris Beveridge (SAMS)

Native Range

3.95 Southern hemisphere, including Chile, Antarctic Peninsula, South Africa, New Zealand (Lambert, 2004).

Invaded Range

3.96 Brittany, France (2002); north-west Spain (2008); Portugal (2009), south and south-east and east coasts of England (2004), south-west and north-west Wales, Northern Ireland (2005), west coast of Scotland and Orkney (Nall *et al*., 2014). Records for *C. eumyota* indicate that this species is particularly prevalent in the south coast of England and coast of Northern Ireland (NBN, 2015).

3.97 From the survey, ten respondents identified other areas where *C. eumyota* had been observed on intertidal and subtidal rock, within marinas and attached to buoys. These areas were all consistent with current observation records for this species (NBN, 2015), with the exception of observations made from the Isles of Scilly (St Mary's Harbour 2009). *Corella eumyota* has not previously been recorded from the Isles of Scilly, with the various islands holding 11 MCZ designations and also being covered by the Isles of Scilly Complex SAC.

MPA distribution

3.98 *Corella eumyota* has previously been recorded in **29 MPAs** in England and Wales, including 10 designated SPAs, 12 designated SACs, one candidate SAC, one designated SCI, one designated Ramsar site, and four designated MCZs (NBN, 2015). From the 17 respondents that had experience of *C. eumyota,* a total of eight identified seven MPAs where this species had been observed. These included Berwickshire and North Northumberland Coast SAC, Fal and Helford SAC, Pembrokeshire Marine SAC, Menai Strait and Conwy Bay SAC, Solent Maritime SAC, Plymouth Sound and Estuaries SAC and Poole Harbour SPA. *Corella eumyota* has been previously recorded within all these MPAs (NBN, 2015). Records of *C. eumyota* from Fowey Estuary were made during Seasearch dives from just outside the MCZ boundary.

Pathway for Spread

3.99 Hull fouling and aquaculture stock transfers are considered the most likely pathways for *C. eumyota.*

Habitat

3.100 *Corella eumyota* is typically found in the low intertidal and shallow subtidal in sheltered locations. This species will colonise artificial substrates, including pontoon floats, but has also been found on natural substrates in muddy or rocky habitats, often amongst boulders or cobbles.

Ecological Impact

3.101 Potential to out-compete native species occupying similar habitats, like the native ascidian Ascidiella aspersa (El Nagar et al., 2010). *Corella eumyota* has exhibited rapid growth rates in introduced habitats, quickly establishing dense monocultures on the submerged surfaces of artificial structures in Portugal in 2008 (El Nagar et al., 2010). Those MPA features that have the potential to be colonised by *C. eumyota*, particularly in low energy environments are summarised in Table 2.

Socio-Economic Impacts

3.102 *Corella eumyota* typically forms tight clumps of individuals by settling on conspecifics. It is possible that in time this species may pose a problem for mussel and oyster growing sites in its introduced range (Bishop, 2011).

3.103 No economic impacts directly relating to the presence and management of *C. eumyota* were noted by the survey respondents.

MPA observations and additional information from the stakeholder survey

3.104 Potential changes associated with the presence of *C. eumyota* within the seven MPAs identified by respondents are summarised together in Appendix E.

Grateloupia turuturu Yamada

Preferred Common Names

3.105 Devil's tongue weed, gracie, red menace and red tide

Synonyms

3.106 *Halymenia sinensis* C.K. Tseng & C.F. Chang, 1984

Domain

3.107 Eukaryota | Kingdom: Plantae | Phylum: Rhodophyta | Class: Florideophyceae | Subclass: Rhodymeniophycidae

Description

3.108 Blades are 10–70 cm long and 2–15 cm broad, pink to dark red in colouration, soft and gelatinous in texture (Figure 13). *Grateloupia turuturu* can be found attached to substratum by small disc-shaped holdfast and short 'stem'. The margins of the blades are either entire or with narrow extensions from their margins (Verlaque *et al*., 2005).

Native Range

3.109 China, Japan, Korea and far-east Russia (CABI, 2015c).

Invaded Range

3.110 Pacific coast of Mexico, Australasia, east coast of North America and Europe (CABI, 2015c). In Europe, *G. turuturu* has been recorded in France, Italy, the Netherlands, Portugal, Spain, Channel Islands and the UK (CABI, 2015c). *Grateloupia turuturu* has been recorded in the UK along the south coast of England and the Isles of Scilly, including the Solent (1969), Southsea (1979), Milford Haven (1984) and the Isle of Wight (1989) and the south coast of Wales.

MPA distribution

3.111 *Grateloupia turuturu* has previously been recorded in **23 MPAs** in England and Wales, including six designated SPAs, six designated SACs, one Ramsar site and designated 10 MCZs (NBN, 2015). The four respondents that stated they had had experience of *G. turuturu* each identified MPAs where this species had been observed. These included Fal and Helford SAC, Plymouth Sound and Estuaries SAC, Solent Maritime SAC and the Isles of Scilly Complex SAC. *Grateloupia turuturu* has been previously recorded within all these MPAs (NBN, 2015).

Pathway for Spread

3.112 Initial sightings of *G. turuturu* have typically occurred in the vicinity of shellfish farms throughout Europe, suggesting initial introduction via commercial shellfish imports. Secondary transfer of established populations is likely via hull fouling and ballast water.

Figure 13. *Grateloupia turuturu* © Rohan Holt (NRW). The image was taken during a survey in Milford Haven in August 2013.

Habitat

3.113 In the North Atlantic, *G. turuturu* occurs on protected and semi-exposed open coastal sites, coastal embayments and harbours, with high tidal currents. The seaweed grows on artificial and natural hard substrata, including rock pools, shells and stones in the low intertidal and the shallow subtidal zone down to a depth of approximately 7 m. *Grateloupia turuturu* species is tolerant to nutrient enrichment and variable temperature (4–29 ºC) and salinity regimes (22–37 PSU), tolerating estuarine as well as marine conditions. Peak growth rate and fertility was recorded in the summer months for plants studied in the UK. Sporelings were found to require temperatures between 15–20 ºC in Rhode Island, USA for optimum development (Gladych *et al*., 2009). In adverse conditions, this species can exist in a crustose form to protect it from environmental stress and grazing (CABI, 2015c).

Ecological Impact

3.114 The large size and rapid reproductive ability via both sporic and vegetative means has enabled *G. turuturu* to out-compete many native macroalgae in the low intertidal and shallow subtidal zones (Barrillé-Boyer *et al*., 2004). *Grateloupia turuturu* can also alter trophic patterns and cause habitat loss (Wallentinus & Nyberg, 2007). Many of the tolerances of *G. turuturu* exceed those of native macroalgae, such as *Chondrus crispus*, *Mastocarpus stellatus* and *Palmaria palmata*, so displacement and/or shading is a possibility within intertidal rocky shores, rock pools and shallow infralittoral rock. Those MPA features that have the potential to be colonised by *G. turuturu*, particularly in low to moderate energy environments are summarised in Table 2.

Socio-economic impact

3.115 No economic impact directly relating to the presence and management of *G. turuturu* were reported by survey respondents.

MPA observations and additional information from the stakeholder survey

3.116 *Grateloupia turuturu* was observed in Fal and Helford SAC, Plymouth Sound and Estuaries SAC (at Wembury), Solent Maritime SAC and the Isles of Scilly Complex SAC on intertidal rock and artificial substrata, with the first records appearing in 2010. No adverse impacts on habitats or features within these MPAs were reported by any respondents.

Summary of NNS and Threatened MPA Features

3.117 Table 2 below summarises those MPA features that are susceptible to colonisation or interaction by either one or more of the eight target NNS under investigation. The summary was compiled from the evidence provided by the literature review both from UK and international studies, expert judgement, proxies for similar habitats and the stakeholder survey results. In each case, the known ecological conditions required for the establishment of the NNS (e.g. intertidal vs subtidal and degree of tolerance to wave exposure) were taken into consideration.

3.118 Table 2 also indicates where there is potential for the NNS to have a negative impact on a particular MPA feature, again based on the literature review and expert judgement. **Caution must be applied here, as data for impacts on specific MPA features is extremely scarce for the majority of the eight target species.** This data was then used to assess the potential impacts of the eight NNS on specific MPAs by cross-correlating the features contained within Table 2 with the MPAs that are designated for those specific features. More details on the potential impacts of the eight NNS on MPAs in England and Wales are found in Section 5.

Table 2. Summary of MPA features that are susceptible to colonisation or interaction with one or more of the eight target NNS. Features have been broadly grouped according to habitat type, with 'Feature Code' relating to the code that defines each habitat under various protected area designations. Preferred habitat energy levels of each NNS are also indicated based on literature review. A '●' indicates where a NNS has the potential to colonise or interact with a habitat type and an '' indicates where there is the potential for a negative impact. The level of impact is not provided. See Section 5 for discussion on assessing level of potential impact*

MPA Feature		**Undaria pinnatifida**	**Ficopomatus enigmaticus**	**Schizoporella japonica**	**Sargassum muticum**	**Hemigrapsus sanguineus**	**Styela clava**	**Corella eumyota**	**Grateloupia turuturu**
Feature Code(s)	**Habitat Type**	**Preferred habitat exposure energy level**							
		Low – moderate	**Low**	**Low – moderate**	**Low – moderate**	**Low – high**	**Low – moderate**	**Low**	**Low – moderate**
	INTERTIDAL SEDIMENTS								
A2.1	Intertidal coarse sediment		●				●	●	●
A2.4	Intertidal mixed sediments		●						
	INTERTIDAL ROCK								
SF_SH_3	Intertidal stony reef	●	●	●		●	●	●	●
A1	Intertidal rock	●	●	●		●	●	●	●
A1.1	High energy intertidal rock					●			
A1.2	Moderate energy intertidal rock	●		●		●	●		●
A1.3	Low energy intertidal rock	●	●	●		●	●	●	●
	INTERTIDAL BIOGENIC HABITATS								
A2.71	Intertidal biogenic reef: *Sabellaria* spp.		●*	●		●	●	●	●

MPA Feature		**Undaria pinnatifida**	**Ficopomatus enigmaticus**	**Schizoporella japonica**	**Sargassum muticum**	**Hemigrapsus sanguineus**	**Styela clava**	**Corella eumyota**	**Grateloupia turuturu**
Feature Code(s)	**Habitat Type**	**Preferred habitat exposure energy level**							
		Low – moderate	**Low**	**Low – moderate**	**Low – moderate**	**Low – high**	**Low – moderate**	**Low**	**Low – moderate**
HOCI_8	Honeycomb worm (*Sabellaria alveolata*) reefs		•	•		•	•	•	•
HOCI_1	Blue mussel (*Mytilus edulis*) beds	•	•	•		•*	•	•*	•
SF_SH_5	Intertidal biogenic reef: mussels	•	•	•		•*	•	•*	•
A2.7	Intertidal biogenic reefs	•	•	•		•	•	•	•
A2.61	Intertidal seagrass beds		•						
	SUBTIDAL SEDIMENTS								
A5.1	Subtidal coarse sediment		•		•		•	•	•
A5.4	Subtidal mixed sediments		•		•				
	SUBTIDAL ROCK								
A3 & A3E	Infralittoral rock	•	•	•	•	•	•	•	•
non_ENG_21	Infralittoral rock and thin mixed sediment	•	•	•	•	•	•	•	•
non_ENG_20	Infralittoral rock and thin sandy sediment	•	•	•	•	•	•	•	•
A3.1	High energy infralittoral rock					•			
A3.2	Moderate energy infralittoral rock	•		•	•	•	•		•

MPA Feature		Undaria pinnatifida	Ficopomatus enigmaticus	Schizoporella japonica	Sargassum muticum	Hemigrapsus sanguineus	Styela clava	Corella eumyota	Grateloupia turuturu
		Preferred habitat exposure energy level							
Feature Code(s)	**Habitat Type**	**Low – moderate**	**Low**	**Low – moderate**	**Low – moderate**	**Low – high**	**Low – moderate**	**Low**	**Low – moderate**
A4 & A4E	Circalittoral rock		•	•		•	•	•	
A4.1	High energy circalittoral rock					•			
A4.2	Moderate energy circalittoral rock			•		•	•		
SF_SH_4	Subtidal stony reef	•	•	•	•	•	•	•	•
	SUBTIDAL BIOGENIC HABITATS								
A5.61	Subtidal biogenic reef: *Sabellaria* spp.		•*	•	•	•	•	•	•
HOCI_16	Ross worm (*Sabellaria spinulosa*) reefs			•	•	•	•	•	•
HOCI_1	Blue mussel (*Mytilus edulis*) beds	•*		•*	•	•*	•*	•*	•
SF_SH_6	Subtidal biogenic reef: mussels	•*		•*	•	•*	•*	•*	•
A5.5	Subtidal macrophyte-dominated sediment	•*		•	•*	•			
A5.53 & HOCI_17	Subtidal seagrass beds				•*	•			
A5.51 & HOCI_12	Maerl beds		•	•	•	•	•	•	•
	SPECIES								
HOCI_14 & SOCI_22	Native oyster (*Ostrea edulis*)	•*	•	•	•	•	•	•*	•

MPA Feature		Undaria pinnatifida	Ficopomatus enigmaticus	Schizoporella japonica	Sargassum muticum	Hemigrapsus sanguineus	Styela clava	Corella eumyota	Grateloupia turuturu
Feature Code(s)	**Habitat Type**	**Preferred habitat exposure energy level**							
		Low – moderate	**Low**	**Low – moderate**	**Low – moderate**	**Low – high**	**Low – moderate**	**Low**	**Low – moderate**
	BROAD HABITATS								
H1170	Reefs	●	●*	●	●	●	●	●	●
RAMSAR_J	Coastal brackish/saline lagoons	●	●	●	●	●			●
H1160	Large shallow inlets and bays	●	●	●	●	●	●	●	●
H1130	Estuaries	●	●	●	●	●			●
HOCI_5	Estuarine rocky habitats	●	●	●	●	●			●
RF_1	Natural or near natural estuary	●	●	●	●	●			●
H1150	Coastal lagoons	●	●	●	●	●	●	●	●
N02	Tidal rivers, Estuaries, Mudflats, Sandflats, Lagoons (including saltwork basins)	●	●	●	●	●			●

Survey Results

3.119 A total of 107 stakeholders were initially sent the survey link. From the 78 responses, 35 provided contact details, 12 from the original list and 23 new respondents. Overall the level of engagement from stakeholders was very encouraging and many responded during the process to say that they had shared the link. The question regarding contact details was deliberately positioned at the end of the survey to ensure that stakeholders were not put off by issues relating to anonymity, particularly with regard to the questions on economic impact. However, many respondents opted not to fill this in or indeed left the survey before it was complete. From those individuals who supplied their contact details, only five represented industry directly. Geographically 63% of respondents who supplied their contact details were based in England, 29% from Wales and 8% from Scotland. This suggests that the proportion of international collaboration was small. This limitation was addressed through the collation of peer-reviewed literature from international sources.

3.120 Figure 14 details the response to the screening question *"Have you seen or had any experience with that particular non-native species?"* broken down by each NNS. For each species of interest, respondents were required to provide an answer for screening questions before progressing with the survey. In instances where no response was given, respondents had closed the survey by that point. Figure 14 shows how the number of respondents leaving the survey increased as the survey progressed. A total of 64% of surveys were completed once begun.

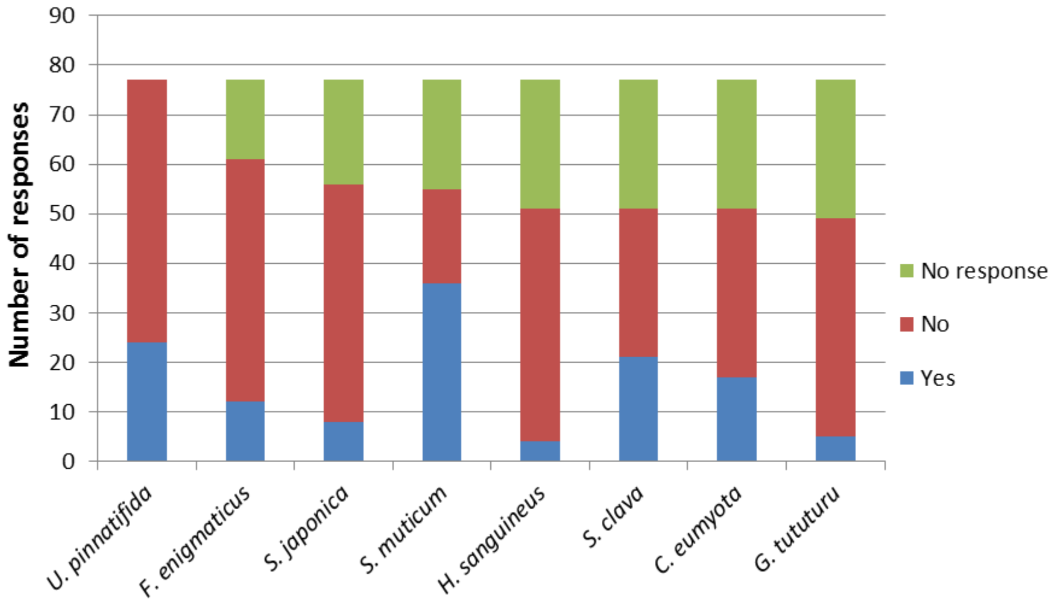

Figure 14. Survey responses to the screening question asking whether they had seen or had experience with the eight NNS. The NNS are shown in order of when they appeared in the survey. A "no response" indicates that the respondent had left the survey at that point

3.121 Respondents had varying levels of experience with the NNS investigated. Figure 15 shows the number of 'yes' responses to the screening question for each NNS as a percentage of total responses (i.e. ignoring all 'no response'). *Sargassum muticum* was the most familiar and well known of the NNS under investigation, with ~65% of responds having had experience of the species. *Hemigrapsus sanguineus*, *Grateloupia turuturu* and *Schizoporella japonica* were the least well known by respondents, with less than 15% of respondents indicating some experience of these NNS.

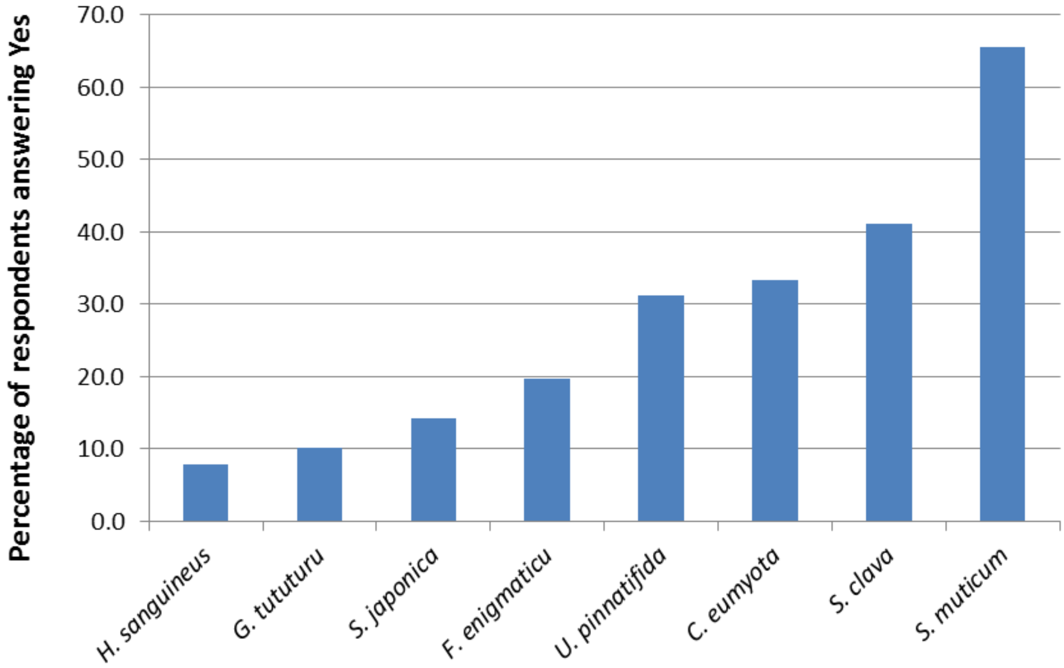

Figure 15. Percentage of respondents answering that they had seen or did have experience with the NNS under investigation. Percentages are given as a function of the number of respondents attempting to answer the screening question

4 Assessing the Ecological Impact on MPA Features

4.1 The assessment of risk is an important step when considering management options where resources are finite. Risk can be defined as the likelihood that a harmful event will occur, multiplied by the magnitude of the consequences if the event occurs (i.e. economic loss, ecosystem damage etc.). Figure 16 shows a conceptual model of how risk can be measured.

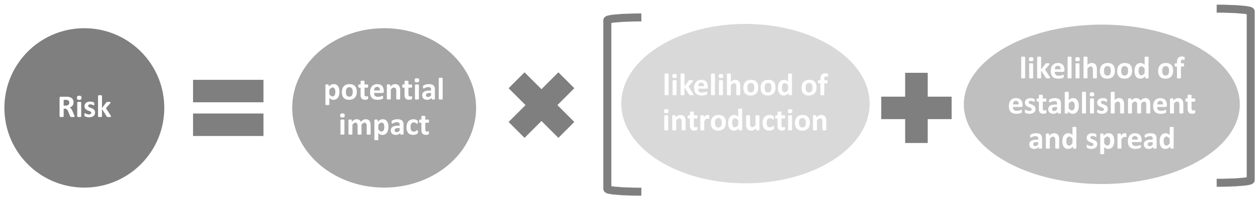

Figure 16. Conceptual model illustrating the elements of risk.

4.2 The risk from NNS is a combination of three main elements:

- **Potential impact –** the severity of the potential threat (economic and ecological)
- **Likelihood of introduction –** the potential of the activities to create a suitable vector capable of carrying and introducing a NNS and/or pathogen
- **Likelihood of establishment and spread –** dependant on the ecological preferences and dispersal potential of NNS and/or pathogens within the recipient environment

4.3 The severity of impact by a NNS on a particular MPA feature is a critical step in the risk assessment process, but understanding the pathways of invasion (i.e. likelihood of introduction) and the likelihood of establishment and spread are equally important to consider when producing a robust risk assessment. Risk assessments carried out by the GB NNSS (www.nonnativespecies.org) provide a useful tool to understand risk associated with NNS. To date only one NNS contained within this report, *Sargassum muticum*, has been formally risk-assessed through the GB NNSS process (in 2011), although *Undaria pinnatifida*, *Grateloupia turuturu*, *Schizoporella japonica* and *Hemigrapsus sanguineus* are currently under review. Unfortunately, no specific information is currently provided within these risk assessments on impacts that the NNS may have on specific MPA features. The information contained within Section 3 of this report is therefore designed to provide managers with a background to understand the relative likelihood of NNS introduction to a particular MPA feature, and the specific conditions (e.g. habitat preferences and environmental tolerances) that favour the establishment of the eight target NNS.

4.4 The likelihood of establishment and spread within MPA features must also be greater than zero in the risk assessment, for there to be the possibility that a NNS could undermine the conservation objectives. In addition to this report, a matrix tool was created to prioritise the MPAs. A ‘traffic light’ system was used to highlight those sites which had features that were susceptible (or already colonised) and the likelihood of introduction of one or more of the eight target NNS (see Supplementary Material – *Matrix for assessing potential impacts of NNS on MPAs in England & Wales*).

4.5 Sixteen of the 112 MPAs assessed were highlighted as 'red' under the matrix traffic system, in that they contained five or more suitable features and appropriate environmental conditions for the establishment by one or more of the eight NNS. Whereas 25 MPAs were considered as 'green', in that the designated features of the site were not suitable for establishment by any of the eight target NNS. Two MPAs, Morecambe Bay SAC and the Exe Estuary SPA, were found to have five or more features susceptible to colonisation (i.e. 'red') by the greatest number of the target NNS (5 out of 8) in this report. Morecambe Bay SPA, Plymouth Sound and Estuaries SAC and Fal and Helford SAC, were also listed as 'red' for 4 out of 8 of the target NNS.

4.6 It is important to note, however, that several assumptions were made for this assessment. They included:

(i) The likelihood of establishment and spread was proportional to the number of suitable features contained within the MPA. MPAs with a greater number of suitable features, therefore, were regarded as a greater risk to establishment by a given NNS
(ii) Features were equally suitable for the establishment of a NNS
(iii) The NNS was equally likely to be introduced to all the suitable MPA features within a particular MPA.

It is recognised, however, that likelihood of introduction will vary between and within MPAs and their features. The traffic light system, therefore, has been devised so that as additional information is collated, the matrix can be easily modified to produce a more accurate assessment of the susceptibility of the particular MPA feature to the colonisation by a particular NNS. For example, more detailed descriptions of sites characteristics (e.g. salinity, temperature and exposure) in addition to incorporating the presence of effective pathways of spread could produce a more accurate assessment of likelihood of NNS introduction and likelihood of establishment and spread. Studies such as that by Pearce *et al*. (2012), which investigates pathways of NNS spread using *Didemnum vexillum* as a case study, offer a potential starting point for these more accurate assessments.

4.7 The matrix tool at present, is limited in its ability to predict the 'level of impact' that a particular NNS may have on an MPA feature. Our ability to assess the likely impacts of the NNS on MPA features in the UK is extremely challenging, particularly since there is such a great paucity in information about their interactions with natural habitats in general. This is particularly true of the majority of the eight target NNS included within this report (e.g. *Schizoporella japonica*, *C. eumyota* and *Styela clava*). Therefore, our ability to prioritise the eight NNS within this report is confounded, since knowledge of their impacts on specific MPA features is incomplete.

4.8 Evidence provided by the literature review and expert judgement, however, suggested that a number of the eight target NNS could potentially cause changes to community structure on certain MPA intertidal and subtidal biogenic features (see Table 2). These features included biogenic reefs (e.g. mussel and *Sabellaria* spp.), subtidal macrophyte-dominated sediment, seagrass beds and native oysters (*Ostrea edulis*).

4.9 Recent guidance on classifying the level of environmental impact on NNS (Blackburn *et al*., 2014) was unsuitable for use with marine NNS (Ojaveer *et al.,* 2015). The conclusions of Ojaveer *et al.* (2015) are worth re-stating, i.e. that the characterisation of marine invasion impacts requires urgent attention and that until this is undertaken, then the precautionary principle must apply and pathways managed to minimise new introductions.

5 Conclusions

5.1 Eight NNS, for which evidence of environmental and socio-economic impacts is currently lacking or has not been reviewed recently in the UK, were selected to assess their potential impact on MPA features listed within England and Wales. This assessment was conducted in three phases; firstly, a review of relevant literature was undertaken to gather information on biology, ecology and known environmental and socio-economic impacts of each NNS. Secondly, a consultation survey was undertaken to confirm and expand on the results of the literature review, drawing together information from stakeholder's experiences and observations. Finally, to inform management options (e.g. Site Monitoring and Improvement Plans and Biosecurity Planning), all the ecological information was drawn together to produce a matrix tool to assess the susceptibility of each MPA and their designated features to establishment by each of the eight target NNS.

5.2 All eight NNS were found in one or more MPAs throughout England and Wales, although observed changes in MPA features were only reported for three of the target NNS including; *U. pinnatifida, Sargassum muticum, and C. eumyota*, whose introduction had led to changes in subtidal macrophyte and ascidian community composition, respectively. Detailed studies on the impacts of many NNS, however, have not been undertaken and it is recommended that the precautionary principle should be applied by authorities involved in the management of NNS and their impacts. For example, if the MPA feature is suitable for colonisation by the NNS, environmental conditions for a site are favourable, and an impact on either the specific feature or a similar proxy has been previously highlighted, then there is a potential that the NNS could cause an unacceptable change to the MPA feature.

5.3 Information provided in Table 2 and the matrix tool provides SNCB staff with details of the MPAs and their features that are potentially susceptible to colonisation or interaction by one or more of the eight target NNS and thus, could be prioritised in any future MPA monitoring programme. Table 2 is intended to serve as a quick reference tool to understand whether the designated MPA contains a feature(s) where the introduction of one of the target NNS could pose a potential threat to a specific feature of the site. The assessor is also encouraged to read the relevant species information in Section 3 to support any assessment made, as potential impacts on MPA features may be dependent on a range of site specific conditions (e.g. prevailing environmental conditions such as temperature and energy levels).

5.4 Assessors should also be aware of the potential socio-economic impacts associated with specific NNS when making their assessment and discussing biosecurity plans with relevant stakeholders.

5.5 Finally, a number of assumptions were made when developing the matrix tool, which can be refined over time, as environmental and monitoring data for specific sites becomes available. It is recommended that further evidence to help determine the point at which a particular NNS may start to have a detrimental impact on a particular feature is essential. For example, at what density a NNS may become an issue and under which circumstances. This will help inform both priorities for any potential management and identify when features are likely to move into unfavourable condition. In the meantime, authorities and SNCBs will need to continue to make a judgement about the above based on the information provided in this report and other literature sources.

Future Recommendations

5.6 Extension of the consultee survey to a more focussed international audience to collate further evidence for impacts of the eight target NNS on specific MPA features. Limited knowledge of the more recently introduced target NNS to the UK resulted in fewer comments from respondents regarding the impacts on MPA features associated with NNS, particularly *G. turuturu*, *Schizoporella japonica* and *H. sanguineus*.

5.7 Inclusion of additional information into GB NNSS review process, and a new section or extension to question 10 in the current GB NNSS risk assessment form. For example, altering question 10 from asking the author to summarise whether a '…*species is causing economic, environmental or social harm*' to whether a *'…species is causing economic, environmental* ***(including any observed changes to MPA features)*** *or social harm'*. This would, therefore, enable the GB NNSS and the SNCBs to justify further monitoring or the instigation of management procedures to be undertaken in a specific MPA.

5.8 Clearer understanding on the point at which a particular NNS may start to have a detrimental impact on a particular feature is essential. It is recommended that further studies are undertaken on specific species that have demonstrated observable impact on MPA features, to provide evidence for an alternative classification system to Blackburn *et al*. (2014) for marine NNS. Once this information exists, the level of threat associated with NNS may be included within this risk assessment process. Improvements made to our understanding of the other components of risk as detailed above will reduce levels of uncertainty further. However, a balance must be struck against resources needed to improve assessments versus the resources saved by producing robust risk assessments.

5.9 Greater evidence of NNS interactions from natural habitats is required. To date, the majority of NNS sightings have been from artificial structures, where processes responsible for the success of the species within these habitats (e.g. altered competitive interactions and predation rates) may vary from surrounding natural habitats. Observations made where particularly suitable conditions on artificial structures may enhance the growth of NNS, can alter the perception of how NNS may behave in natural habitats. Therefore, whilst the collection of information from a large number of observers can help build a picture of the current extent of changes associated with a particular species, focussed studies producing quantitative or semi-quantitative data are required to assess the extent of observed changes on specific MPA features (see Table 2). This will help to understand the scale of the impact or the likelihood of future impacts.

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Appendix A

The table below provides a list of the MPAs (and their associated designations) that was looked at during this study.

Alde, Ore and Butley Estuaries SAC	Isles of Scilly Complex SAC
Alde-Ore Estuary SPA	Isles of Scilly: Bishop to Crim MCZ
Aln Estuary MCZ	Isles of Scilly: Bristows to the Stones MCZ
Bae Caerfyrddin/ Carmarthen Bay SPA	Isles of Scilly: Gilstone to Gorregan MCZ
Bae Cemlyn/ Cemlyn Bay SAC	Isles of Scilly: Hanjague to Deep Ledge MCZ
Beachy Head West MCZ	Isles of Scilly: Higher Town MCZ
Berwickshire and North Northumberland Coast SAC	Isles of Scilly: Lower Ridge to Innisvouls MCZ
Blackwater, Crouch, Roach and Colne Estuaries MCZ	Isles of Scilly: Men a Vaur to White Island MCZ
Burry Inlet SPA	Isles of Scilly: Peninnis to Dry Ledge MCZ
Cardigan Bay/ Bae Ceredigion SAC	Isles of Scilly: Plympton to Spanish Ledge MCZ
Carmarthen Bay and Estuaries/ Bae Caerfyrddin ac Aberoedd SAC	Isles of Scilly: Smith Sound Tide Swept Channel MCZ
Chesil and the Fleet SAC	Isles of Scilly: Tean MCZ
Chesil Beach and Stennis Ledges MCZ	Kenfig/ Cynffig SAC
Chichester and Langstone Harbours SPA	Kingmere MCZ
Coquet Island SpA	Lands End and Cape Bank SAC
Cumbria Coast MCZ	Limestone Coast of South West Wales/ Arfordir Calchfaen de Orllewin Cymru SAC
Deben Estuary SPA	Lindisfarne SPA
Dee Estuary/ Aber Dyfrdwy SAC	Liverpool Bay / Bae Lerpwl SPA
Drigg Coast SAC	Lizard Point SAC
Dyfi Estuary / Aber Dyfi SPA	Lundy MCZ/SAC
Essex Estuaries SAC	Lyme Bay and Torbay SAC
Exe Estuary SPA	Margate and Long Sands SAC
Fal and Helford SAC	Medway Estuary and Marshes SPA
Farne Islands SPA	Medway Estuary MCZ
Flamborough and Filey Coast pSPA	Mersey Estuary SPA
Flamborough Head SAC	Mersey Narrows and North Wirral Foreshore SPA
Folkestone Pomerania MCZ	Morecambe Bay SAC/SPA
Fylde MCZ	Mynydd Cilan, Trwyn y Wylfa ac Ynysoedd Sant Tudwal SPA
Gibraltar Point SPA	North Norfolk Coast SAC/SPA
Glannau Aberdaron ac Ynys Enlli/ Aberdaron Coast and Bardsey Island SPA	Northumbria Coast SPA
Glannau Môn: Cors heli / Anglesey Coast: Saltmarsh SAC	Orfordness - Shingle Street SAC
Grassholm SPA	Outer Thames Estuary SPA
Haisborough, Hammond and Winterton SAC	Padstow Bay and Surrounds MCZ
Humber Estuary SAC and SPA	Pagham Harbour MCZ/SPA
Pembrokeshire Marine/ Sir Benfro Forol SAC	Thames Estuary and Marshes SPA
Pen Llyn a`r Sarnau/ Lleyn Peninsula and the Sarnau	Thanet Coast MCZ/SAC

SAC	
Plymouth Sound and Estuaries SAC	The Dee Estuary SPA
Poole Harbour SPA	The Manacles MCZ
Poole Rocks MCZ	The Swale SPA
Portsmouth Harbour SPA	The Wash and North Norfolk Coast SAC
pRamsar	The Wash SPA
Ramsar	Torbay MCZ
Ramsey and St David`s Peninsula Coast SPA	Traeth Lafan/ Lavan Sands, Conway Bay SPA
Ribble and Alt Estuaries SPA	Tweed Estuary SAC
Severn Estuary SPA	Upper Fowey and Pont Pill MCZ
Severn Estuary/ Môr Hafren SAC	Whitsand and Looe Bay MCZ
Shell Flat and Lune Deep SAC	Y Fenai a Bae Conwy/ Menai Strait and Conwy Bay SAC
Skerries Bank and Surrounds MCZ	Ynys Feurig, Cemlyn Bay and The Skerries SPA
Skokholm and Skomer SPA	Ynys Seiriol / Puffin Island SPA
Skomer MCZ	
Solent and Isle of Wight Lagoons SAC	
Solent and Southampton Water SPA	
Solent Maritime SAC	
Solway Firth SAC	
South Dorset MCZ	
South Wight Maritime SAC	
Start Point to Plymouth Sound and Eddystone SAC	
Stour and Orwell Estuaries SPA	
Studland to Portland cSAC	
Tamar Estuaries Complex SPA	
Tamar Estuary MCZ	
Teesmouth and Cleveland Coast SPA	

Appendix B

The table below details the organisations from which the consultees that were sent the survey link belonged. 107 consultees were initially sent the survey link, and there were 23 new respondents from further circulation of the survey among those originally contacted.

Angling Cymru	IFCA Isles of Scilly	Offshore Shellfish Ltd.
Angling Trust	IFCA Kent and Essex	Oyster farmer and academic
Bangor mussel producer	IFCA North Eastern	Peelports - Quality Management Representative
Bangor University	IFCA North Western	Salacia-Marine
Biodiversity Ireland	IFCA Northumberland	Scottish Natural Heritage
British Ports Association	IFCA Southern	Scottish Renewables
Canoe England	IFCA Sussex	Scottish Salmon Producers Organisation
Cawthron Institute, New Zealand	Inshore Fisheries and Conservation Authority	Seafood Scotland
Chamber of Shipping	Irish sea fisheries board	Seasearch
City and County of Swansea	Joint Nature Conservation Committee	Swansea University
Clyde Forum	Louhs-Agency	Solway Firth Partnership
Cornwall Wildlife Trust	Maldon Oysters	The Centre for Environment, Fisheries and Aquaculture Science
Duchy Oysters	Management Scheme/relevant coastal partnership officer	The Field Studies Council
Dwr Cymru Welsh Water	Marine Biological Association of the UK	The Scottish Environment Protection Agency
Environment Agency	Marine Institute	UKMPG - executive
Environmental Policy advisory for the Maritime and Coastguard Agency	Marine Management Organisation	University of Wales Trinity Saint David
Fowey Harbour Commissioners	Marine Scotland	Welsh Fisherman's Association
GB Non Native Species Secretariat	MDL Marinas	West Country Mussels (St Austell Bay, Cornwall)
Green Blue	Milford Haven Port Authority Environmental manager	West Mersea Oystermen
Hampshire & Isle of Wight Wildlife Trust	National Oceanography Centre	WFD Alien species Group
Head of Sea Bed Users Group	Natural England	Wildlife and Countryside link
IFCA Cornwall	Natural Resources Wales	Yorkshire Wildlife Trust
IFCA Devon and Severn	North East Lincs Council	
IFCA Eastern	North Sea Living Seas Manager	

Appendix C

An electronic copy of the survey questionnaire circulated to all stakeholders is available as a standalone document.

Appendix D

Summary of stakeholder survey responses detailing ecological changes and impacts associated with the presence of *Sargassum muticum* within MPAs. NB A '-' indicates question was left blank by respondent

MPA Name	No. of Respondents	Date First Recorded	Habitat / Feature	Changes Observed	Impact on Conservation Objectives	Spatial Influence	Time Scale of Influence
Cumbria Coast	1	2015	Rocky shore and rock pools	No	-	Localised and low abundance	-
Fal and Helford	1	-	Seagrass and rocky shore habitats	-	Not sure. Survey results due early next year	Widespread	-
Morecambe Bay	1	2011	Cobble and boulder substrate	Not known	Data not sufficient to make a judgement on this	Data not sufficient to make a judgement	Data not sufficient to make a judgement
Solent Maritime	1	2006	Rocky shore habitat but also shingle areas.	-	-	-	>5 years
Start Point to Plymouth Sound and Eddystone	1	-	Infralittoral rock	-	-	-	-
Whitsand and Looe Bay	1	2013	Intertidal rocky shore - moderate energy / sheltered	*S. muticum* was the most abundant seaweed in patches. Seems to be favoured by stalked jellyfish, so now viewed as a change in biodiversity rather than wholly negative presence.	No	Throughout the whole MCZ	2-5 years or more
Carmarthen Bay and Estuaries	3	2000	Intertidal reefs, rock pools and surge gullies	Shading in rock pools	No. Does not seem to be a significant impact. May complement native species to some extent - refuge etc. May provide similar functional niche.	Patchy and localised but increasing on Worms Head Causeway, and on Port Eynon Point.	>5 years

MPA Name	No. of Respondents	Date First Recorded	Habitat / Feature	Changes Observed	Impact on Conservation Objectives	Spatial Influence	Time Scale of Influence
Menai Strait and Conwy Bay	3	2010	Sublittoral fringe	Density gradually increased and now completely dominates the sublittoral fringe reducing the population of *Saccharina latissima* and potentially other algal and epiphytic species. However, one respondent indicated that coverage had become sparser.	Change in distribution of typical species of reef features. However, one respondent indicated no change.	Widespread, covering approximately a quarter of the Menai Strait, equating to approximately 1/8th of the intertidal reef in the SAC.	>5 years. When first evident the coverage was significantly higher subsequently it appears to be confined to certain locations and restricted to the shallow subtidal.
Pembrokeshire Marine	5	2000	Intertidal reefs, rock pools and mixed substrate	Shading in rock pools, limited at each site to just a few pools - not extended across the sites over the years.	No.	Patchy distribution among *Fucus* spp.	>5
Plymouth Sound and Estuaries	2	2005	Intertidal and subtidal reefs	No	No	Widespread	None
Lundy	2	1999	Sublittoral fringe, Landing Bay (rock pools)	Visually dominant in places. *S. muticum* is now widespread across the island and whilst Keith Hiscock has carried out some small studies on its impact, to date there seems to be no overall negative consequence to its presence - this is probably due to the overall health of the island’s ecosystem.	No. Possible impact on 'naturalness' if that is an objective.	In 2000, it was recorded across the south end of the Landing Bay, northern edge of Rat Island and spreading northwards through Landing Bay. Now its distribution is localised but in several locations.	>5 years

Appendix E

Summary of stakeholder survey responses detailing ecological and impacts associated with the presence of *Corella eumyota* within MPAs. NB A '-' indicates question was left blank by respondent

MPA Name	No. of Respondents	Date First Recorded	Habitat / Feature	Changes Observed	Impact on Conservation Objectives	Spatial Influence	Time Scale of Influence
Berwickshire and North Northumberland Coast	1	2012	Beneath boulders in the mid-shore zone	NA	No evidence to suggest conservation objectives are affected. Small isolated clusters of individuals that don't appear to be displacing/smothering native species at present.	Localised, small patches	More patches seem to be appearing since 2012 but this could be because we're more aware of them now.
Poole Harbour	1	Aug-15	Seagrass beds	Not significantly altering biotope composition	No	Was localised in some seagrass bed patches, but absent in other seagrass beds, so localised	-
Menai Strait and Conwy Bay	1	2010	Under boulders and epifauna on *Fucus serratus*	No	Possible shift in distribution to typical species on reef features	Widespread in sheltered areas of rocky reef, including *Fucus serratus* on cobbles	Roughly doubling in population size from 2010 to 2014
Pembrokeshire Marine	1	2012	Sublittoral jetties and intertidal boulders	No	No	Very low abundance	-
Plymouth Sound & Estuaries	1		Rock intertidal and marina	-	-	-	-
Solent Maritime	1	2010 at Keyhaven, but not until at least 2013 for other sites.	Attached to hard substrata - usually small pebbles / boulders	-	-	Quite widespread throughout the Solent area	-
Fal and Helford	2	2009	Subtidal rock and artificial substrata	Not significantly altering biotope composition	No	Only found isolated individuals	-