Monitoring and surveillance for non-indigenous species in UK marine waters

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Executive Summary

The threat non-indigenous species (NIS) pose to global biodiversity loss is considered to be second only to habitat destruction since NIS have devastated terrestrial, freshwater and marine ecosystems across all continents. Marine systems are particularly vulnerable to the introduction of NIS due to their exposure to multiple transport pathways along which new species can be either accidentally or intentionally introduced. There has been a steady rise in the number of NIS becoming established in UK waters, increasing the level of impact and cost to the environment and economy.

In recognition of the increasing issues resulting from the introduction of NIS on the marine environment the European Union adopted the Marine Strategy Framework Directive 2008/56/EC (MSFD) in 2008, specifically descriptor 2. The MSFD provides a legislative framework for an ecosystem based approach to the management of human activities which supports the sustainable use of marine goods and services. The over arching aim of the Directive is to achieve Good Environmental Status (GES) by 2020 in Europe's marine waters.

In order to assess GES there is a need to gather information on the status of NIS in marine waters in comparison to environmental targets. In addition, monitoring and surveillance is required to determine the effectiveness of a programme of measures (re: bio-security) in reducing the risk of introduction.

This study aims to provide information to aid in the formation of a monitoring and surveillance programme for marine NIS for the delivery of the MSFD within UK waters by assessing the potential for existing monitoring programmes to be contribute to these requirements.

The main findings of the study are:

- There are a large number of non-statutory monitoring programmes that have contributed to our current understanding of marine NIS occurrence and distribution.
- Some statutory programmes have contributed to this knowledge base already.
- In combination the non-statutory and statutory monitoring programmes provide good coverage for the detection and monitoring of NIS in coastal waters, although temporal coverage of monitoring sites is difficult to determine.
- Off-shore monitoring sites will contribute to our understanding of the current distribution of some NIS in addition to making up part of an early warning system for new arrivals.

- NIS records gathered from these monitoring programmes are not always reported in such a way that they contribute to the common understanding of their distribution.
- There is currently no routine survey work targeting locations at high risk of introduction of NIS (e.g. ports and marinas). Ad-hoc surveys conducted at these locations are rarely made available to contribute to current understanding.

The main recommendations from this study are:

- The establishment of a baseline from which further monitoring can be assessed.
- The development of a target species list.
- The remit of statutory monitoring programmes are extended (where required) to include NIS.
- Identification procedures to be established for difficult to identify or novel species.
- Identification of a single data repository.
- Establishment of a verification process for monitoring.
- Establish a risk based surveillance programme at hotspot locations.

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1 Introduction

1.1 Background

The threat non-indigenous species (NIS) pose to global biodiversity loss is considered to be second only to habitat destruction since NIS have devastated terrestrial, freshwater and marine ecosystems across all continents (Mack *et al.* 2000; Bax et al. 2003). NIS have the potential to out-compete and displace native species having negative effects on ecosystem functions and services (Shiganova 1998; Grosholz 2000). Marine systems are particularly vulnerable to the introduction of NIS due to their exposure to multiple transport pathways along which new species can be either accidentally or intentionally introduced. Marine NIS can have detrimental effects on marine infrastructure (piers and pipelines) and marine based industries such as shipping and offshore exploration (Eno 1996). There has been a steady rise in the number of NIS established in UK waters (Roy et al. 2012), increasing the level of impact and cost to the UK environment and economy.

In recognition of the increasing issues resulting from the introduction of NIS (and other human activities) on the marine environment the European Union adopted the Marine Strategy Framework Directive 2008/56/EC (MSFD) in 2008, specifically descriptor 2. The MSFD provides a legislative framework for an ecosystem based approach to the management of human activities which supports the sustainable use of marine goods and services. The over arching aim of the Directive is to achieve Good Environmental Status (GES) by 2020 in Europe's marine waters. Descriptor 2 relating to NIS states:

"Non-indigenous species introduced by human activities are at levels that do not adversely alter the ecosystems."

Council Decision 2010/477/EU provides additional information on how GES should be achieved in relation to the MSFD. The criteria and indicators listed within 2010/477/EU and the UK's response to these are listed below:

Criteria 2.1- *Abundance and state characterisation of non-indigenous species, in particular invasive species.*

UK proposals to address Criterion 2.1- *Reduction in the risk of introduction and spread of non-native species through improved management of high risk pathways and vectors.*

Indicator 2.1.1- *Trends in abundance, temporal occurrence and spatial distribution in the wild of non-indigenous species, particularly invasive non-indigenous species, notably in risk areas, in relation to the main vectors and pathways of spreading of such species.*

UK proposals to address Indicator 2.1.1- *Surveillance indicator looking at the abundance, distribution and number of new introductions of NIS in areas which are at a high risk of new introductions (with a view to being able to develop a baseline for the rate of establishment of new NIS).*

Prevention of introduction is increasingly recognised as the most effective means of avoiding or mitigating the impacts associated with unwanted NIS. Indeed, the guiding principles in the NIS management espoused by the Convention on Biological Diversity (CBD) are hierarchical in structure (Wittenberg & Cock 2001) and emphasize preventive measures over eradication, containment, control and mitigation. One of the main methods of preventing introductions is to manage the pathways by which NIS can be introduced. Pathway management of NIS is complex, especially in the marine environment, where multiple pathways may result in introductions occurring anywhere around the coast. Pathways may involve either accidental or intentional movement of species as a consequence of human activities (Ruiz & Carlton 2003; Copp *et al.* 2005). Marine NIS have established due to escapes from aquaculture, fouling of vessels' hulls, transport in ballast or bilge water, accidentally with imports of aquaculture stock and by drifting or rafting, on either man-made or natural materials, from areas where the species is non-indigenous (Eno *et al.* 1997). Many of these activities can take place over considerable distances, connecting previously disparate regions of the globe. Those pathways involving vessel movements (fouling of hulls and ballast water) are often cited as the highest risk routes for the introduction of marine NIS (Carlton, 1992) and this concurs with the finding that the hotspots for NIS in British waters are areas with a high volume of shipping traffic, such as the Solent (see Tidbury et al. 2014).

1.2 Monitoring and surveillance

In order to assess GES there is a need to gather information on the status of NIS in UK waters in comparison to environmental targets. In addition, monitoring and surveillance is required to determine the effectiveness of a programme of measures (re: bio-security) in reducing the risk of introduction.

The criterion and indicator listed above considers both introductions of new NIS (or horizon species) in addition to the further spread of NIS already present in UK waters with particular emphasis on invasive NIS. It is therefore appropriate that any programme is divided into two parts in the assessment of indicators: monitoring the spread of existing NIS and surveillance for new introductions.

Monitoring and surveillance programmes should build upon and integrate existing monitoring programmes where possible while being adaptive to enable appropriate reaction to changes in the marine environment and emerging issues (e.g. the introduction of a new NIS, additional horizon species being indentified).

It is worth noting that the majority of marine NIS are found and impact on coastal regions (Eno et al. 1997; Bax, et al. 2003). It is therefore important that monitoring and surveillance focuses on areas where NIS are likely to occur. Off-shore monitoring and surveillance can, however, still be useful as an early warning process, especially in the detection of species introduced via natural dispersal on ocean currents or utilising off-shore platforms and structures as stepping-stones to introduction.

1.2.1 Monitoring requirements

There are over 74 NIS marine species found in UK waters including alga, plants, invertebrates and fish; the majority of which are found in coastal and/or estuarine environments. The NIS currently found in the UK have varying degrees of distribution, some being found in a few locations (such as *Didemnum vexillum*) while other are found along large stretches of the coast (such as *Crepidula fornicata*). Given the broad and varying distribution of the NIS already present within the UK, a monitoring programme developed to detect their presence and assess their distribution will need to cover a range of different species and habitat types. Implementing a specific programme to monitor NIS currently present in UK waters will be expensive and time consuming, it is therefore proposed that current monitoring programmes undertaken in the marine environment are assessed to determine their suitability for the detection and assessment of NIS. Current monitoring programmes fall broadly into 2 categories, statutory and non-statutory.

Ideally a monitoring programme should be optimised to detect the further spread of NIS once introduced. Using a risk based approach in the development of monitoring, assessing where the risk of spread may be the greatest, would be one such way in achieving this, however, these locations would need to be identified through a process similar to that produced for introductions (Tidbury et al. 2014). This has not be developed at the time of writing, therefore any monitoring programme developed will not be risk based, but will need to attempt to provide as broad coverage as possible.

1.2.2 Surveillance requirements

The criterion, indicator and the UK proposed responses focuses on a risk based approach to both management and surveillance of marine NIS. The principle behind risk based surveillance is the efficient use of resources directed towards high risk locations, animal types and geographic areas (Stärk et al 2006), ensuring resources are focused on where the likelihood of introduction is greatest, so that the sensitivity of the system (i.e. the capacity to identify new introductions) is optimised (Oidtmann et al., 2013). A process has been developed by which locations considered at high risk from potential introductions can be indentified (Tidbury et al. 2014). This provides an indication of where surveillance should be focused to optimise detection.

Focusing all efforts on high risk locations, however, can reduce the effectiveness of a surveillance programme, with reduced probability of detecting potential introductions at low risk sites (Tidbury et al. 2014). This may result in establishment and spread of NIS introduced from low risk sites prior to their detection. It is therefore proposed that while a risk based approach to surveillance is taken, with an emphasis on locations identified as high risk, there is also assessment of lower risk sites but at a lower frequency.

1.3 Target species

The criteria and indicators, while applying to all NIS, particularly apply to invasive NIS. This emphasises the risk based approach to implementation, with the higher risk NIS (i.e. those that are invasive and therefore likely to have greatest impact) being the main target for monitoring, surveillance and management. Attempting to develop a monitoring and surveillance programme consisting only of existing programmes which assesses all known marine NIS will be a significant challenge, especially in relation to additional work load and effective identification of such a large range of species by a varied work force. Targeting monitoring and surveillance at those species that are considered to have the greatest impact will reduce the work load and make identification less complicated without significant compromise to the programme.

Target species are often compiled into living lists that are up-dated regularly when new species are identified. Determining what is invasive and which criteria should be used in quantifying invasiveness has been much debated. Several methods for identifying and ranking the impact of invasive NIS exist with varying degrees of complexity. In the UK methodology has been developed by the GB Non-Native Species Secretariat (GB NNSS) for risk ranking species. The UK Alien Species Group (UK ASG) has used this process in the creation of target species lists for the Water Framework Directive monitoring

requirements, focusing primarily on freshwater species. The total number of marine and transitional water species currently on the lists is 41 (7 high impact, 4 moderate impact, 9 low impact and 21 unknown impact). Of the 41 species listed 11 have had completed risk assessments.

While ideally a monitoring programme should be able to report on all NIS, the minimum requirements would be that a target species list is detectable. For a surveillance programme, in addition to the target species list, horizon species (or those species that are not currently present but are of concern) should also be included. A horizon scanning process, identifying potential invasive NIS is conducted periodically by the Non-Native Species Information Portal (NNSIP). This procedure has recently been conducted and 11 potential invasive marine NIS were identified (Roy et al. 2014). Since the completion of this process one of the species identified on the list, the Asian Shore Crab (*Hemigrapsus sanguineus*) has been identified as being present in two locations in the UK.

1.4 Data storage and management

There are a number national databases used in the UK for the storage and management of marine biological data, including information relating to the distribution of NIS. Data are provided from a range of monitoring programmes which varies depending on the nature/objective of the database. There is a degree of overlap with some databases populated from the same monitoring programmes. Information on the majority of databases relating to NIS (e.g. meta data) is comparatively sparse, this is due to the lack of national routine or statutory monitoring and surveillance programmes specifically designed for the detection of marine NIS conducted in UK waters. A table summarising the main databases is presented in annex 7.1 of this document.

One of the key information systems for NIS monitoring and surveillance is the GB Non-Native Species Information Portal (GB-NNSIP). The GB-NNSIP is an on-line information system involving a network of organisations such as volunteers and voluntary bodies, statutory bodies and local record centres. The GB-NNSIP is dynamically linked to the National Biodiversity Network (NBN) Gateway. Together these systems provide a central database, consisting of a species register, containing information on taxonomy, dates and pathways of introduction, habitat and synonyms, in addition to fact sheets providing descriptions, photographs of the species as well as information on their biology, ecology, habitat, range, impact and related literature. Occurrence data are stored on the NBN Gateway. The GB-NNSIP data custodian for the marine environment is the Maine Biological Association (MBA), who provide a quality assurance process for information as part of its role as data custodians. Despite having the GB-NNSIP/NBN Gateway network in place the data it holds may not always be current and exhaustive. For example, data on the distribution of NIS may be stored on other databases (e.g. British

Oceanographic Data Centre) and there may be a delay in transfer of data to NBN from databases such as Marine Recorder. To get a clearer picture of the current information held on the distribution of NIS currently found in UK waters these databases will need to be interrogated for relevant information.

1.5 Objectives

The aim of this report is to provide information to aid in the formation of a monitoring and surveillance programme for marine NIS for the delivery of the MSFD within UK waters. Specifically this report will:

1. Undertake an assessment of existing monitoring programmes in the marine environment; this will include those undertaken under existing commitments (e.g. WFD) in addition to voluntary work (e.g. Seasearch). Information collected will include:
    i) What data the monitoring programme records
    ii) Methodology used
    iii) Where data is stored
    iv) How frequently the monitoring programme is conducted
    v) What environment the monitoring covers (e.g. marina, benthic, pelagic)
    vi) which geographical area is covered
    vii) How species are identified (e.g. on site or following return to the laboratory)
2. From the above assessment of existing monitoring programmes, their suitability for detection of marine NIS and invasive species will be examined. This will be done by:
    i) Assessing if the monitoring programme has detected a NIS previously.
    ii) Determining the suitability of the programme to detect certain taxonomic groups, using specific known NIS as illustrative examples.
    iii) Examine what adaptations to the existing monitoring programme will need to be made (if any) for inclusion in a NIS monitoring programme.
    iv) Assess the geographical coverage of the monitoring programmes in relation to high risk areas and pathways.
    v) Compare geographical coverage of the monitoring programmes to the known distribution of NIS.
3. From the above assessment evidence based advice will be provided on the formation of NIS monitoring based on existing programmes, gaps in the possible programme will be identified and recommendations made on how these could be filled.

2 Non-statutory monitoring

2.1 Overview

There are a number of non-statutory marine biological survey programmes that detect and report the presence of NIS including new introductions. These programmes will fall into one or more of the following categories:

- Utilise volunteers and members of the public to collect data.
- Regional in scale rather than national.
- Ad-hoc non-routine (i.e. the work is not conducted as part of a routine monitoring programme).
- Do not directly fill any legal obligation for the marine environment.

2.2 Category of programmes

There are a considerable number of programmes that fall under the broad heading of 'non-statutory' in the marine environment. It would therefore be impossible to list all such programmes, however, below is a summary of those that have reported information relating to NIS to the GB-NNSIP. This demonstrates that the studies within these programmes are capable of and have detected marine NIS. The programmes fall under the following broad categories:

- Recording schemes
- Societies
- Research groups and organisations
- Local record centres/recording groups

2.2.1 Recording schemes

- *RISC – Recording Invasive Species Counts* is a Defra funded project aimed at encouraging interest in invasive species and to encourage the public to record sightings. The programme is aimed at collecting information on a select number of species and is run by the Centre for Ecology and Hydrology (CEH), National Biodiversity Network, Anglia Ruskin University and GBNNSS.

- *The Shore Thing* – is an initiative of the Marine Life Information Network (MarLIN) that works with schools and community groups to collect information on the marine life of rocky shores around GB. The information is collected by volunteers and collated and made available on line.
- *Sealife Tracker and AquaInvaders* – are mobile phone applications aimed at collating data on invasive species and climate change indicators in the marine/aquatic environment. They are operated as a partnership between the British Sub Aqua Club, the Marine Biological Association, the Environment Agency, Scottish Natural Heritage, the Scottish Environment Protection Agency, the University of Bristol and the Biological Records Centre. The project seeks to engage divers, boat owners, fishermen and other members of the public to collect data using their mobile phone.

2.2.2 Societies

- *Seasearch* – is a project co-ordinated by the Marine Conservation Society which aims to map marine habitat and biodiversity by using a network of volunteer divers. The project is supported by a wide range of government and non-government organisations from across GB.
- *British Phycological Society* – is a charity devoted to the study of algae. It is a long establishment society that publishes the European Journal of Phycology. The society supports the recording and mapping of seaweeds from around Britain and Ireland.
- *The Conchological Society of Great Britain and Ireland* – is devoted to the study of molluscs. The society runs a range of recording schemes and runs field meetings where survey work is undertaken.
- *The Porcupine Society* – are interested in marine natural history of the North East Atlantic and Mediterranean. The aims of the society are to promote the understanding and stimulate interest of the marine environment. The society holds regular field meetings where survey work is conducted.
- *The Marine Biological Association (MBA)* – is a registered charity that aims to promote scientific research into all aspects of the marine environment. The MBA are involved in the gathering of information in relation to marine biodiversity, including NIS, through projects such as MarLIN, The Shore Thing, MARClim (which include a suite of marine NIS that are surveyed regularly), in addition to members' surveys and educational events.

2.2.3 Research groups and organisations

There are a number of academic groups and organisations with specialist interest in specific taxa of NIS or geographical regions that contain NIS whose work has significantly contributed to knowledge of distributions and temporal occurrence. Much of this information is stored on the Data Archive for Seabed Species and Habitats (DASSH) and made available to the GB-NNSIP/NBN Gateway network. For example, data on NIS has been gathered via the Aliens project I and II run by MBA, SoS and SAMS and submitted to the sent to NBN. Examples of information presented from ad-hoc academic studies includes the distribution of *Styela clava* in the Fal and Helford estuaries that was collected as part of a PhD studying *Sabella pavonina* in 1995.

2.2.4 Local Record Centres /recording groups

Local Record Centres (LRCs) are organisations that collect, collate, manage and disseminate information relating to the biodiversity and geodiversity of a region. LRCs are usually established through a partnership of interested parties, in order to bring together local information on wildlife and supply this to local users. Figure 1 illustrates the coverage of the LRCs. Information is gathered from a broad range of groups active in the area the LRC covers. Information presented to an LRC for example by a local university may also be put onto DASSH in addition to appearing on other databases depending on the original funding route. LRC will also hold unique information, not present elsewhere.

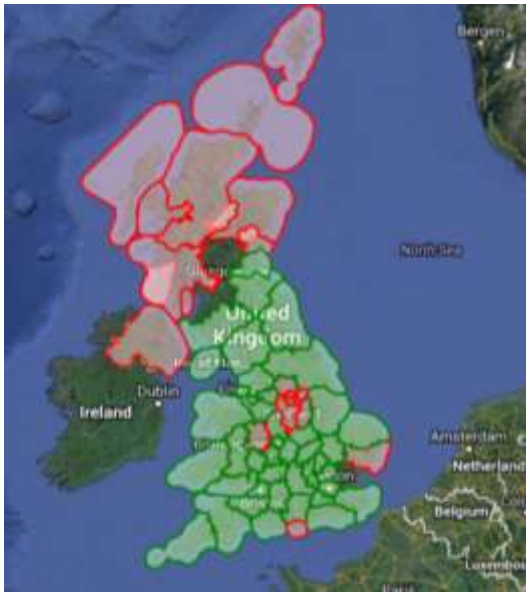

Figure 1. Coverage of Local Record Centres in GB (from the Association of Local Record Centres website). Areas marked in green are ALRC members and red are non-members.

3 Statutory monitoring

3.1 Overview

There is currently no targeted national statutory monitoring and surveillance programmes specifically designed for the detection of marine NIS conducted in UK waters. There are, however, several statutory monitoring programmes that have the potential to contribute to a UK wide monitoring/surveillance programme for NIS. Some programmes already do record some NIS and contribute to the current understanding of their distribution. These include:

- Marine Protected Areas (MPA) monitoring
- The Clean Seas Environmental Monitoring (CSEMP)
- Groundfish Surveys
- Monitoring of dredged material disposal sites-SLAB5
- Aggregate Levy Sustainability Fund monitoring
- Water Framework Directive

The following is a brief review of each of these monitoring programmes including their primary objectives, temporal and spatial coverage, their ability to detect NIS, if and how NIS may have previously been reported, and how modifications can be made, if required, to increase suitability for their inclusion in a monitoring programme.

3.2 MPA monitoring

3.2.1 Background

Marine Protected Areas (MPAs) are zones of the seas and coasts where habitats and species are protected from damage and disturbance. The UK Government is committed to contributing to a well-managed network of MPAs by 2016 to meet commitments under the Marine and Coastal Access Act, Birds and Habitats Directive, Convention on Biological Diversity, and to contribute to measures aimed at achieving Good Environmental Status across Europe's seas by 2020 under the EU Marine Strategy Framework Directive. There are a number of different types of MPA designations in the UK including; Special Areas of Conservation (SACs), Special Protection Areas (SPAs), Ramsar sites, Sites of Special Scientific Interest (SSSI) (England, Scotland and Wales) and Areas of Special Scientific Interest (ASSI) (Northern Ireland), Marine Conservation zones (MCZs) and Scottish MPAs (SMPA). Currently there are

108 SACs with marine components, 88 of which are in inshore waters, 16 in offshore waters and 4 which straddle both inshore and offshore waters. SACs are designated for habitats and species listed under the Habitats Directive. In addition, the UK also has 108 SPAs with marine components, 3 of which are entirely in the marine environment. The most recent type of MPA designation is facilitated by the Marine and Coastal Access Act (MCAA) 2009 which has allowed the creation of MCZs which can protect a range of nationally important marine species, habitats, geology and geomorphology. In 2013, 27 MCZs were designated in English and Welsh waters. Scotland has used the Marine Scotland Act and the UK's MCAA to propose possible Scottish MPAs (SMPAs). Possible Scottish MPAs include Nature Conservation MPAs, Demonstration/Research MPAs and Historic MPAs. Figure 2 provides a graphical representation of the geographical distribution of the inshore and offshore locations covered under this category.

Figure 2. Location of Marine Protected Areas including: recommended Marine Conservation Zones (rMCZ) in England and those sites designated in 2013, UK Special Areas of Conservation (SAC), UK Special Protection Area (SPA) and possible Scottish MPA.

3.2.2 Information recorded

MPA survey data collection currently includes; multibeam bathymetry, intertidal, side scan sonar, and environmental ground truthing (grabs for infauna and video data and diver surveys for epifauna)

providing standardised data on the presence and extent of habitats and species at sites around the UK.

3.2.3 Methodology used

Inshore and offshore MPAs are surveyed using a range of survey platforms including public sector vessels (e.g. Cefas RV Endeavour and 3 EA vessels) and commercial companies (through an ITT process), diver surveys and data from loggers. Multibeam bathymetry and side scan sonar is preferentially acquired ahead of groundtruth operations to confirm the presence and extent of features of interest. Groundtruthing operations consist of grab samples for infauna (abundance and biomass - quantitative) and video tows with still photographs (semi-quantitative at best) and diver surveys for habitat and epifauna surveys. Species are identified by expert taxonomists for both infauna from grab samples and epifauna on video tow files and associated still photographs and during diver surveys in accordance with standard laboratory practices, and the results are checked following the recommendations of the National Marine Biological Analytical Quality Control (NMBAQC) scheme (Worsfold and Hall, 2010). Video and photographic stills are processed in accordance with the guidance documents developed by Cefas and the JNCC for the acquisition and processing of video and stills data (Coggan and Howell, 2005; JNCC, in prep.). Infauna and epifauna data (abundance and biomass) from grab, video and diver surveys are stored on Marine Recorder. Intertidal surveys require sampling across sediment, rock and saltmarsh habitats from high water springs to low water springs following specific techniques described in Wyn et al. 2000).

3.2.4 Frequency of monitoring

Currently MCZ sites are being visited for site verification and baseline condition surveys. Once designated, site specific monitoring programmes will be put in place for MCZs. For SACs, sites are reported on in a 6 year cycle and monitoring tends to be site specific. SACs have a minimum sampling frequency of every 18 years and a maximum frequency of every 4, but some examples of annual or multiple surveys per year exist (e.g. NRWs Benthic Rock Monitoring).

3.2.5 Detection of NIS

While to date the detection of NIS by MPA monitoring has not been reported it is considered likely that the programme will be able to report on a broad range of NIS including infaunal and epifaunal species. A short study conducted as part of this work (see annex 7.2) was conducted to determine the effectiveness of MPA monitoring in the detection of NIS. This work concludes that MPA monitoring is

sufficient to detect NIS. With the creation of a species list and the development of a reporting protocol there would be little further modifications required for the MPA programme to form part of a NIS monitoring scheme.

3.3 The Clean Seas Environmental Monitoring Programme (CSEMP)

3.3.1 Background

CSEMP fulfils the UK's commitment to European directives including its mandatory monitoring requirements under the Oslo and Paris Convention (OSPAR) Joint Assessment Monitoring Programme (JAMP). The programme provides a coordinated approach to environmental monitoring in the UK's coastal and estuarine areas.

The general aims of CSEMP are to:

- Detect long-term spatial and temporal trends in physical, biological and chemical variables at selected estuarine and coastal sites
- Support consistent standards in national and international monitoring programmes for marine environmental quality
- Establish appropriate protective regulatory measures
- Coordinate and optimise marine monitoring in the UK
- Provide a high quality chemical and biological data set from the UK’s marine environment

CSEMP sampling by Cefas includes intermediate and open seas around England and Wales. CSEMP in Scotland covers; Inner Seas off the West Coast of Scotland, Irish Sea, North Atlantic Ocean and North Sea (see figure 3 below). It should be noted that a large proportion of the monitoring sites are offshore.

3.3.2 Information recorded

- Concentrations of ammonium, chlorophyll pigment, dissolved oxygen, nitrate, nitrite, phosphate, silicate, temperature and salinity in the water column.
- Concentrations of carbon and other organic contaminants, polychlorobiphenyls (PCBs), polycyclic aromatic hydrocarbons (PAHs), inorganic chemical composition of sediment or rocks, nitrogen and sediment grain size parameters.
- Concentration of organic contaminants and other substances, polychlorobiphenyls (PCBs), polycyclic aromatic hydrocarbons (PAHs) in biota and metals in biota and **f**ish morphology,

age and physiology, zoobenthos taxonomic abundance and taxonomy-related wet weight biomass per unit area of the bed.

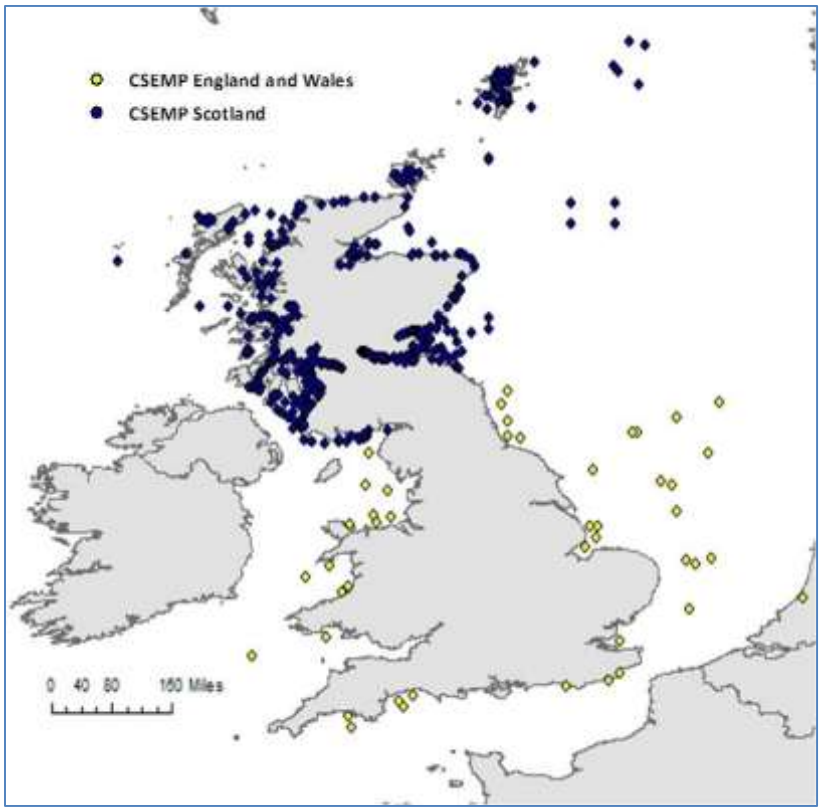

Figure 3. CSEMP sampling locations in English and Welsh waters surveyed by Cefas (yellow) and CSEMP sampling locations in Scottish waters sampled by Marine Scotland Science and the Scottish Environment Protection Agency (SEPA).

3.3.3 Methodology used

Cefas is responsible for CSEMP sampling in intermediate and open seas around England and Wales, while Marine Scotland Science and the Scottish Environment Protection Agency (SEPA) are responsible for CSEMP monitoring in Scottish waters. Fish, epifaunal and infaunal organisms, sediment and water samples including phytoplankton species composition are assessed as part of this survey programme. Most samples for the programme are collected during an annual multidisciplinary cruise in June/July. Fish, benthos, sediment and water samples are taken from a total of around 45 fixed stations in intermediate and open seas around England and Wales. Additional water samples are also collected during the winter months from opportunistic stations to fulfil eutrophication monitoring commitments. Fish and epifaunal species are identified by experts at the point of sampling. Infaunal samples are identified by taxonomic experts post collection. Data is stored in the following- Marine Environment and Monitoring Assessment National Database (MERMAN), the British Oceanographic Data Centre (BODC) currently manages the MERMAN database. Data from MERMAN is then

transferred to ICES and OSPAR to fulfil UK monitoring commitments. Data held in MERMAN is also used for national assessments such as Charting Progress 2. All Competent Monitoring Authorities (CMAs) undertaking monitoring for the CSEMP use the programmes' monitoring manual, the Green Book. A Marine Monitoring Protocols Manual is currently being developed to make sampling standards and protocols used in UK marine monitoring programmes publicly available. All laboratories contributing data must participate in the relevant AQC schemes; Biological Effects Quality Assurance in Monitoring Programmes (BEQUALM): National Marine Biological Analytical Quality Control scheme (NMBAQC); Quality Assurance of Information for Marine Environmental Monitoring in Europe (QUASIMEME).

3.3.4 Frequency of monitoring

Data is collected annually (June/July) by Cefas. Due to budget constraints, not all stations are visited every year. On odd years, stations east of the Isle of Wight are sampled and on even years stations west of the Isle of Wight. Previously, sediment and fish from a number of Scottish sea areas were monitored annually whilst other sea areas (e.g. Forties, Hebrides) have not been monitored. Following a recent review, the frequency of monitoring contaminant groups and biological effects has been reduced to monitoring every 6 years where concentrations are below Background Assessment Concentrations (BACs) and are stable or declining. Monitoring is conducted every three years where concentrations are above BACs but below Environmental Assessment Criteria (EACs), or if BACs are showing an upward trend. Annual monitoring will only continue if concentrations are greater than the EQS/EAC/ERL/EC food level or above the BAC and showing an upward trend. Areas not currently monitored but where concentrations are expected to be low should be sampled on a rolling basis every 6 years.

3.3.5 Detection of NIS

The CSEMP survey is likely to be able to detect a range of NIS including fish, epifauna, infauna and plankton. It is one of the few statutory monitoring programmes that would be able to detect the presence of NIS of plankton and therefore important to include in a NIS monitoring programme. There have been previous reports of NIS made from CSEMP, illustrating that the programme is capable of detecting NIS. The development of a target species list, a reporting protocol and some additional training of experts in identification would increase the robustness of this programme in the reporting of NIS.

3.4 Ground fish surveys

3.4.1 Background

The ground fish surveys aim to obtain information on the distribution, size composition and abundance of all fish, commercial shellfish and cephalopod species. The age-length distribution of selected species is recorded for ICES in addition to biological parameters of selected commercial species. Data collected from the survey has been used in the assessment of fish stocks. Secondary objectives of the survey include the collection of benthic, sedimentary and hydrographic information, in addition to the assessment of marine litter caught in trawls. The groundfish survey is comprised of a number of separate surveys (e.g. Eastern English Channel Survey and English North Sea Survey). There may be slight differences in the main objectives between the surveys e.g. the fish species being targeted, but the principle behind the surveys remain the same. Figure 4 below shows the distribution of sample sites where the majority of sites are off-shore.

Figure 4. Distribution of sample sites used as part of the ground fish survey.

3.4.2 Information recorded

Survey prioritisation is the assessment of fish species (which species will vary between regions covered); quantification of marine litter and epifaunal catch in trawls. Incidental information on infaunal species and sedimentary and hydrographical data is collected on an ad-hoc basis as secondary objectives.

3.4.3 Methodology used

The survey currently uses a variety of trawl types (depending on region and target fish species) to assess fish, epifaunal benthos and litter. All fish species are identified and measured, while benthos is identified and mass determined. The catch is sampled by expert staff and total catch weight and length distributions for all species caught are recorded using the Cefas Electronic Data Capture system. Data from this survey is stored on the ICES data portal, DATRAS, an online database of trawl surveys. DATRAS has an integrated quality check utility. All data, before entering the database, have to pass an extensive quality check.

3.4.4 Frequency of monitoring

Ground fish surveys are carried out during July/October annually. The same station positions are surveyed each year.

3.4.5 Detection of NIS

NIS have been reported from ground fish surveys previously, though infrequently, (for example *Crepidula fornicata*) demonstrating that the sampling methodology may enable the detection of NIS. The development of a target species list, reporting protocol and training of experts in identification would increase the robustness of this survey programme for the detection of NIS.

3.5 Monitoring of dredged material disposal sites- SLAB5

3.5.1 Background

Sites classified as open for the disposal of dredge material are monitored under the SLAB5 'Monitoring of dredged material disposal sites'. There are approximately 365 of these sites around the UK coast. Information is gathered to assess biological impact as well as to address public concerns. Figure 5 presents those sites designated as dredge extraction sites and the sample station locations used over the last 5 years.

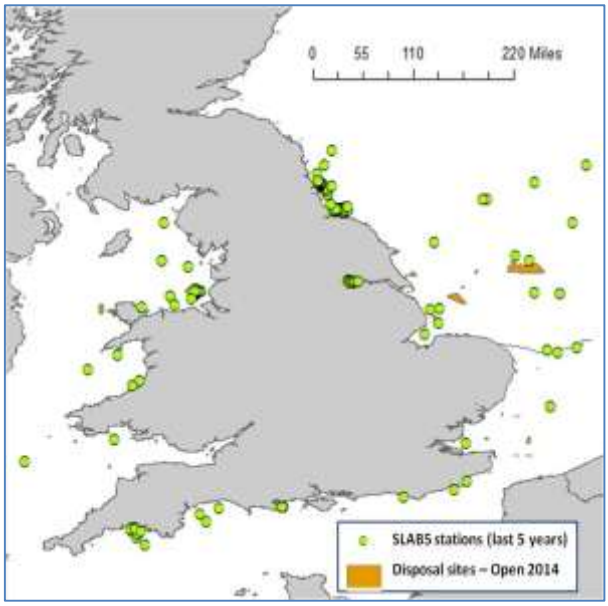

Figure 5. Location of dredge disposal sites classified as open (Feb 2014) in orange and SLAB5 station locations from the last 5 years.

3.5.2 Information recorded

A range of information is gathered including sidescan and multibeam data, sediment particle size distribution, levels of sediment based organic carbon and nitrogen, macrofaunal communities (abundance and biomass), Sediment Profile Imagery (SPI), and sediment contaminants (TBT, PAHs, organohalogens, and trace metals) at surveyed sites.

3.5.3 Methodology used

Samples are collected from fixed locations, the macrofaunal samples are collected using grabs. Benthic samples are identified to the lowest taxonomic level, mainly by external consultants, with all information reported. Macrofauna data are stored on UNICORN. Data quality and assurance for the benthic samples is assessed using standard AQC procedures in the NMBAQC.

3.5.4 Frequency of monitoring

Frequency of monitoring is site specific depending on the frequency and quantity of dredge disposal activities and other issues that may arise such as public concern, so there is a risk based element to site selection. For some sites this may be ad-hoc, but some monitoring will be done most years although this is not an annual programme. The number of sites being monitored may be relatively low. For example, in 2014 five sites will be monitored, with macro-faunal data being collected at two of these.

3.5.5 Detection of NIS

There have been no previous reports of NIS from the SLAB5 monitoring programme; however, this may be a result of data not having been assessed for their presence. As the macro-faunal samples are identified to the lowest taxonomic level if a NIS was present in any of these samples, then they would have been detected. With the development of a target species list and adjustments to the reporting protocol this programme would provide a useful addition to a NIS monitoring programme.

3.6 Aggregate Levy Sustainability Fund (ALSF) Monitoring

3.6.1 Background

Material is currently extracted from around 70 licensed extraction areas located around the coasts of England and Wales. These areas are located in seven dredging regions including the Humber, East Coast, Thames, Eastern English Channel, South Coast, Bristol Channel and North-West. For dredging activities that are likely to have a significant environmental effect, it is required that the benthic fauna in the area is characterised. The likely impact of the project on the fauna is considered and monitoring undertaken over the license term. Figure 6 provides a graphical representation of the current aggregate sites under licence around England and Wales.

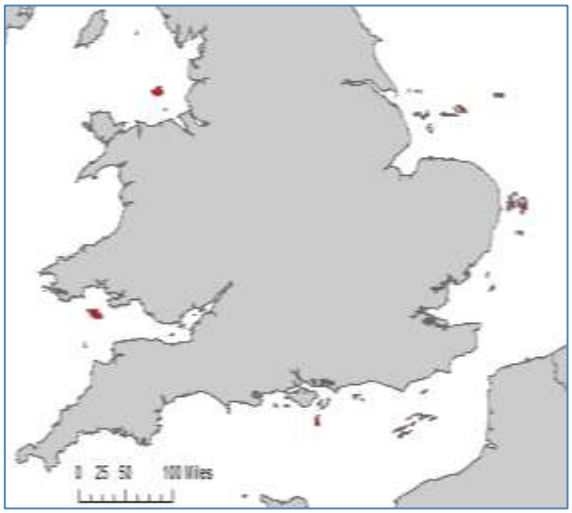

Figure 6. Location of aggregate sites which have a current licence for extraction around the coast of England and Wales.

3.6.2 Information recorded

Acoustic and habitat (sediment and faunal communities) data is collected for proposed extraction sites. Infaunal, epifaunal, fish communities and habitats (sediments) data is also recorded.

3.6.3 Methodology used

Benthic characterisation surveys recording the presence and extent of benthic habitats and their faunal communities within and around predicted zones of influence are required at the pre-application stage. This forms a pre-dredge survey, providing a baseline to which on-going and post-extraction monitoring can be compared. In data poor areas, this can be achieved using approximately 120 individual benthic samples (grabs and trawls) for a typical licence. There is also a requirement for control stations to understand patterns of natural variability in benthic communities over time, away from sites impacted by extraction. To achieve this, Time-Series Data and Environmental Assessment Reference Stations (EARS), involving the collection of 4 replicate grab samples are taken at each station to assess infaunal abundance, biomass and particle size analysis (PSA) of sediments. A new regional approach to environmental monitoring (Cooper, thesis) will soon be implemented. The new approach will be fundamentally based on the collection of sediment samples for PSA as, theoretically, so long as sediment composition remains within this range then it should be possible for the return of the original faunal assemblage after dredging. However, a regional 'baseline' characterisation for macrofauna and sediments is needed, from which, a suitable number (to be determined using power analysis) of stations will be selected as long-term benthic monitoring stations. Species are processed and identified by taxonomic experts to the lowest taxonomic level; all species are identified and quantified. Currently data collected for monitoring of aggregate sites are held by the company and the consultants whom collect the data on their behalf. Species should be processed following AQC procedures, NMBAQC's guidelines for infaunal sample processing. Any 'new' species identified from the given survey should be incorporated into the laboratory reference collection.

3.6.4 Frequency of monitoring

Frequency of monitoring is site and licence specific and will depend on the sensitivity of the environment and the amount of material being removed in a given area or time. Monitoring should be carried out at the same time of the year as the baseline survey.

3.6.5 Detection of NIS

Some data relating to the presence of NIS has been made available through the ASLF and via the Crown Estate website. There are plans in progress for data from this survey to be made available on MEDIN. Given the level of detail recorded, with the inclusion of a target species list and reporting protocol that provided accesses to the data then this survey could contribute to a NIS monitoring programme.

3.7 Water Framework Directive (WFD)

3.7.1 Background

The Water Framework Directive covers inland waters (surface water and groundwater), transitional waters and coastal waters out to 1nm from shore. Article 8 of the Water Framework Directive (WFD) sets out the requirements for the monitoring of surface water status, groundwater status and protected areas:

"Monitoring programmes are required to establish a coherent and comprehensive overview of water status within each river basin district."

The objective of monitoring is to establish an overview within each River Basin District. It should also permit the classification of all surface water bodies into one of five classes and groundwater into one of two classes. Figure 7 shows the WFD survey locations used from 2010-2012.

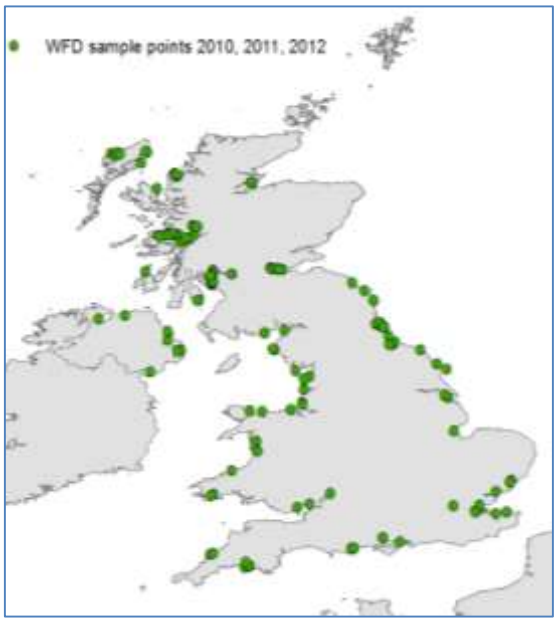

Figure 7. Location of Water Framework Directive survey locations around the coast of the UK from the years 2010, 2011 and 2012

3.7.2 Information recorded

Monitoring conducted for the WFD covers a wide range of habitats in both intertidal and subtidal environments. Intertidal surveys for macroalgae, seagrass, saltmarsh and invertebrates and subtidal surveys for fish in estuaries and invertebrates in estuaries and coastal waters are undertaken. Ad-doc sampling is also conducted for nuisance algae as part of bathing waters monitoring in the summer.

3.7.3 Methodology used

A wide range of techniques are used to address the varied surveys carried out for this programme. For example, quadrat surveys are used for opportunistic macro-algae, seagrass and saltmarsh surveys along with core sampling for invertebrates. For subtidal surveys a Day grab is used to sample infaunal communities. A range of fishing techniques are employed for estuarine fish surveys. Seine and fyke nets from the shore, and beam and subtidal otter trawls are deployed from small and large vessels. Samples are analysed and species identified by a combination of relevant Government Agency experts (e.g. EA, NRW and SEPA) and external consultants: the rocky shore macro-algae identification is undertaken by consultants; opportunistic macro-algae survey identification is done by relevant government agencies, seagrass and saltmarsh survey identifications are done by relevant government agencies, invertebrate and phytoplankton identifications are done by external consultants and fish identification is done by relevant government agencies . Quality management is through operational instructions and participation in the NMBAQC invertebrates and fish programme. There is ongoing development on quality procedures for macroalage, saltmarsh and phytoplankton monitoring. In England, data is stored on the EA database BIOSYS and the National Fish Population Database (NFPD). Data and or metadata may also be found on Marine Recorder and DASHH. Some information is reported directly to the National Biodiversity Network (NBN) Gateway.

3.7.4 Frequency of monitoring

Different elements of the programme are monitored over different time scales. For example rocky shore macro-algae surveys are undertaken 1 in 3 years, opportunistic macro-algae surveys 2 in 3 years (maybe dropping to one in 3), seagrass surveys on an annual basis, saltmarsh surveys 1 in every 6 years, invertebrate surveys are carried out 1 in 3 years both interidally and subtidally, while fish samples are taken on a bi-annual basis and phytoplankton samples annually at present but may be reviewed next year.

3.7.5 Detection of NIS

Currently there is no specific monitoring for NIS under the WFD, instead reports are made on incidental recordings as part of the routine monitoring to assess changes in NIS populations. NIS are considered an extra step in the reporting for WFD where the latest list of NIS of concern are considered in the context of any records in the monitoring. A list of species of concern has been developed by the UK ASG. There have been several reports of NIS made to date as a result of WFD monitoring efforts including report from grab samples to the NBN, and *Eriocheir sinensis* (Chinese mitten crab) reports

to DASSH. NIS data has also been received from the Scottish Environment Protection Agency (SEPA) and Natural Resource Wales (NRW) as part of their WFD monitoring programmes. This illustrates that procedures currently in place are able to detect NIS. With an MSFD target species list and reporting procedure the WFD monitoring programme could contribute to a MSFD programme as well.

3.8 Consultancies

There are a number of commercial consultancies that undertake work in the marine environment and gather information on species distribution and abundance. Environmental Impact Assessments (EIAs) are an example of work undertaken by consultancies which contains species information that may include NIS. EIAs are likely to occur in locations where developments are being undertaken such as ports and marinas as a result of legal requirements under relevant legislation. Currently this information is not available as it is commercial in nature, but may provide useful data on the distribution of NIS, especially those in high risk locations. It is important to note that environmental surveys are likely to be required for the application for exemptions under the Ballast Water Management Convention. Given that surveys undertaken for such applications will be conducted in harbours and ports which may be high risk in nature, this information will be useful to have, but again is likely to be collected through commercial contracts.

4 Spatial and temporal coverage

4.1 Introduction

A number of non-statutory and statutory marine monitoring programmes have been identified as potential contributors to a MSFD NIS monitoring and surveillance programme. While the potential suitability of the monitoring programmes in the detection of NIS has been established, the spatial and temporal coverage in relation to high risk locations and the known distribution of invasive NIS needs to be assessed to fully determine how effective the adoption of these programmes would be in delivery of surveillance and monitoring programmes. It is impossible to assess the coverage of the non-statutory monitoring programmes given their ad-hoc nature; however, the coverage of the statutory monitoring programmes can be examined to some degree. In this section the coverage of the programmes listed in section 3 of this report is assessed for both spatial and temporal coverage, in addition to being compared to high risk areas of introduction and current information on the distribution of selected high impact invasive species. Please note that only UK monitoring programmes were considered in this report whereas high risk areas of introduction were assessed for both UK and Ireland.

4.2 Spatial coverage

In assessing the spatial coverage of the statutory monitoring programmes included in section 3 all of the possible monitoring sites used by the surveys have been plotted on a single map (see figure 8). In some cases such as with the MPA programme there are no specific monitoring sites, but areas that are monitored; in these cases the information has been presented as polygons.

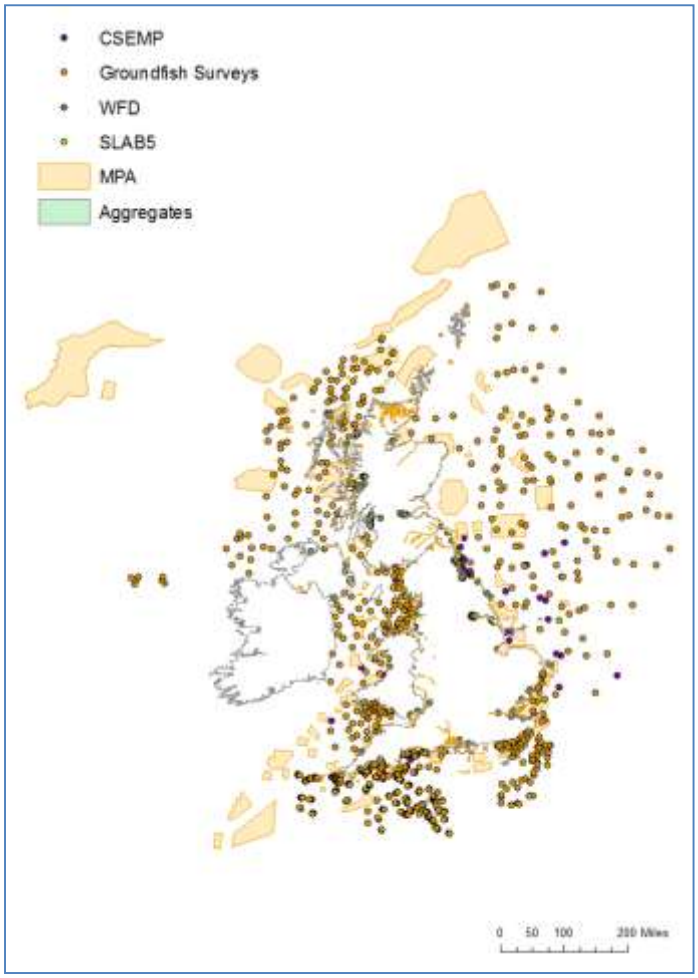

Figure 8. Monitoring sites of the statutory monitoring programmes. Please note that both designated and potential MPAs are included.

As can be seen from figure 8 the programmes being considered have both on-shore and off-shore sites. As NIS are more likely to be detected in and impact inshore waters (Bax et al. 2003), sites that are within 1 nautical mile (NM) of the coast may be considered most relevant to monitoring and surveillance programmes. Table 1 shows the total number of sites from each monitoring programme found within 1 NM of the coast. It should be noted that off-shore sites will still play an important role in assessing the distribution of some NIS found in deeper waters (e.g. *Crepidula fornicata*) in addition to an early warning system for new arrivals.

Table 1. The total number of monitoring sites under each monitoring programme, the total number and proportion found within 1 nautical mile of the coast and the total number and proportion found further than 1 NM from the coast.

Monitoring programme	Total number of sites	Number (Proportion) of sites within 1 NM of coast	Number (proportion) of sites further than 1 NM from coast
CSEMP	48	0 (0%)	48 (100%)
Groundfish survey	949	4 (0.4%)	945 (99.6%)
WFD	194	194 (100%)	0 (0%)
SLAB5	367	34 (9.3%)	333 (90.7%)
MPA	12,877	12,235 (95%)	642 (5%)
Aggregates	90	0 (0%)	(100%)

A map showing the distribution of the monitoring sites associated with different programmes located within 1 NM has been produced (figure 9). To further visualise monitoring coverage, an assessment of presence of monitoring sites found within 1 NM of the coast within coastal grid squares (Tidbury et al. 2014) has been made. This illustrates the total number of statutory monitoring programmes that have monitoring sites within each grid square (see figure 10). In the case of programmes where monitoring sites have been represented as polygons the polygon is counted once for each grid square that it's located within. From this, it is possible to identify potential gaps in monitoring i.e. where there are currently no monitoring sites for any programme. Interpretation of this information needs to be made in consideration of the temporal coverage.

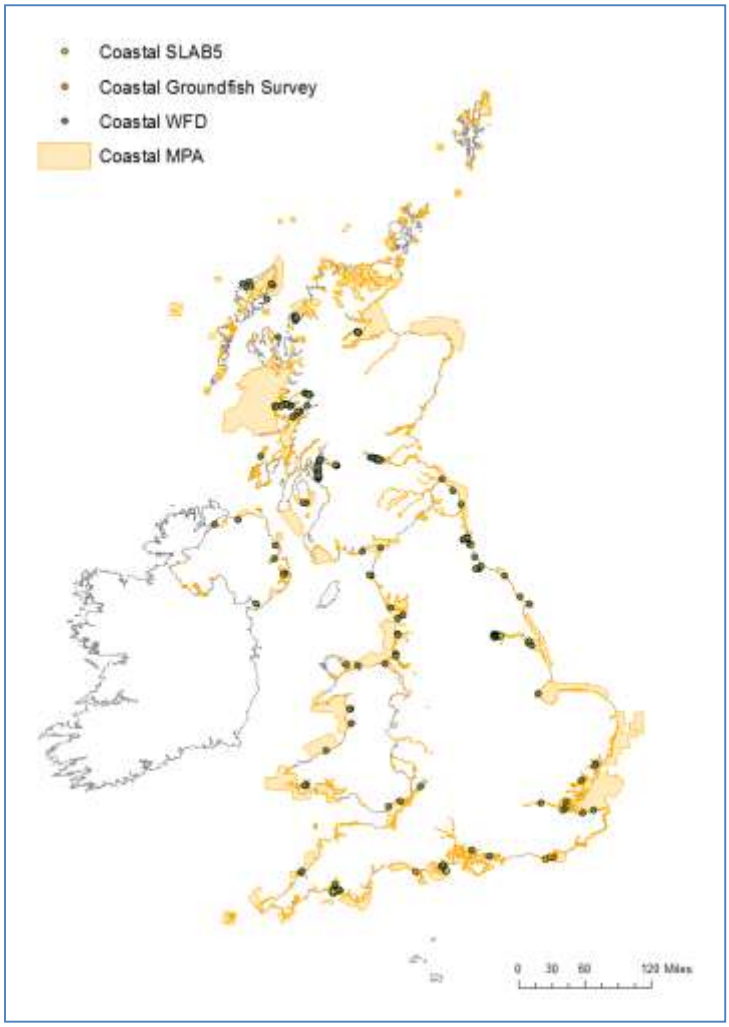

Figure 9. Map of monitoring sites founds within 1 NM of the coast. Where the monitoring sites have been represented by polygons the entire polygon has been included even where they extend beyond the 1 NM mark. Please note that both designated and potential MPAs are included.

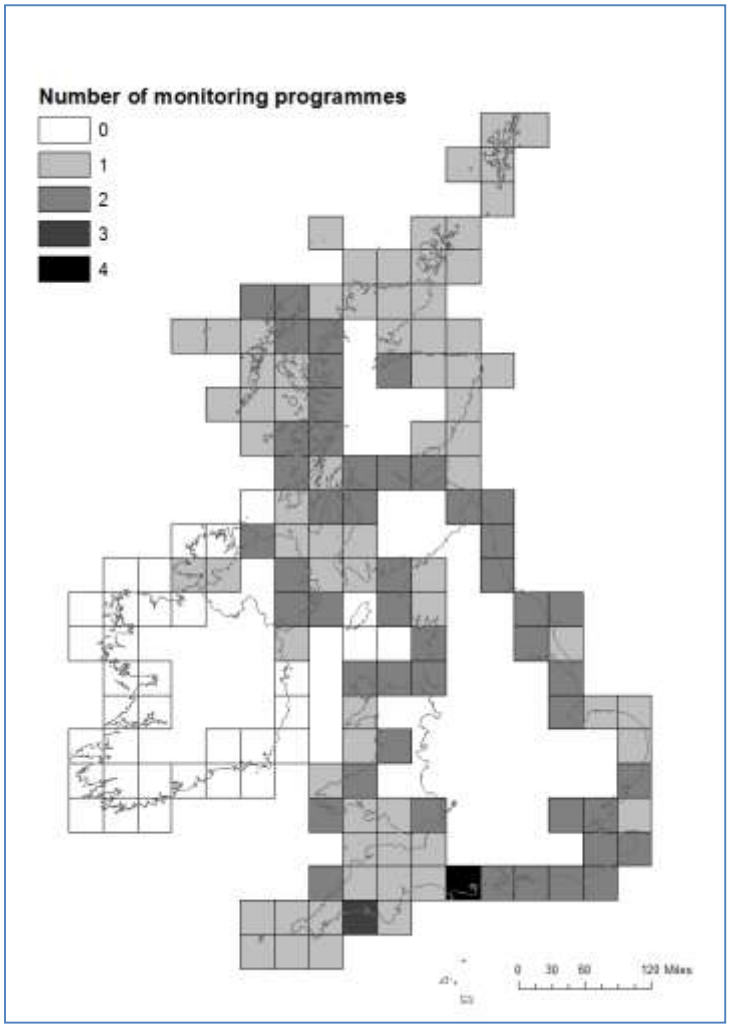

Figure 10. Coverage of monitoring programmes located within 1 NM of the coast. Scores refer to the number of different monitoring programmes for which monitoring may be undertaken in each grid square. For example, a monitoring programme with a score of 2 has the potential for monitoring by 2 monitoring programmes to be undertaken within it.

4.3 Temporal coverage

All of the monitoring programmes (both statutory and non-statutory) use a number of monitoring sites, however, the frequency and order of visits vary between monitoring programmes. For example, SACs have a maximum sampling frequency of 18 years, but some are visited annually. In other cases the programmes are delivered as part of a rolling programme, where all sites are visited over a number of years, for example CSEMP sites, where half of the sites are visited one year and the other half the next. In other cases monitoring sites are selected on a risk based approach, such as SLAB5 sites where out of the 360+ sites only a handful will be surveyed each year (e.g. in 2014 only 5 sites were surveyed). Other factors can also affect site selection such as financial constraints, licensing, and resource availability or how developed the monitoring programme currently is (e.g. MPAs). As a result of all of the factors, it is difficult at this point to categorically state where monitoring will take place within a

given time period. It is, however, possible to estimate the number of sites that may be visited per annum based on the frequency information gathered (see table 2), but the location of these sites is not possible to determine. The estimations of the number of sites that may be surveyed within any given year are based on the frequency information gathered in section 3. In some cases the frequency information is very specific (e.g. groundfish surveys visit 100% of all sites), but in the case of the MPA surveys there is a broad range in the frequency of visit. In the case provided in table 2 the estimated number of sites to be visited has been based on a worst case scenario, e.g. MPA sites will be visited only once every 18 years. In other cases such as with the aggregates monitoring an estimate has been made on the potential number of licences that could be issued in a given year, although this may vary.

Table 2. The total number of monitoring sites under each monitoring programme and the estimated number that would be visited in a given year. The number and proportion of these sites found within 1 NM of the coast is also provided.

Monitoring programme	Total number of sites	Estimated number of sites to be surveyed per annum	Number (proportion) within 1 NM
CSEMP	48	24	0
Groundfish survey	949	949	4 (0.4%)
WFD	194	154	154 (100%)
SLAB5	367	5	1 (0.27%)
MPA	12,877	715	679 (95%)
Aggregates	90	5	0

4.4 Coverage in relation to high risk locations

Locations have been identified where introductions of NIS are considered most likely to occur (Tidbury et al. 2014). Assessing coverage of monitoring in relation to high risk locations is important in determining if current monitoring will be sufficient for the implementation of a risk based surveillance programme. At this point only a risk based surveillance programme is considered as locations at high risk of spread have not yet been determined. Figure 11 presents a graphical representation of the number of monitoring sites in relation to locations considered at high risk from introductions. Please note that only UK monitoring programmes were considered in this report whereas risk of introduction was assessed for both the UK and Republic of Ireland in Tidbury et al (2014).

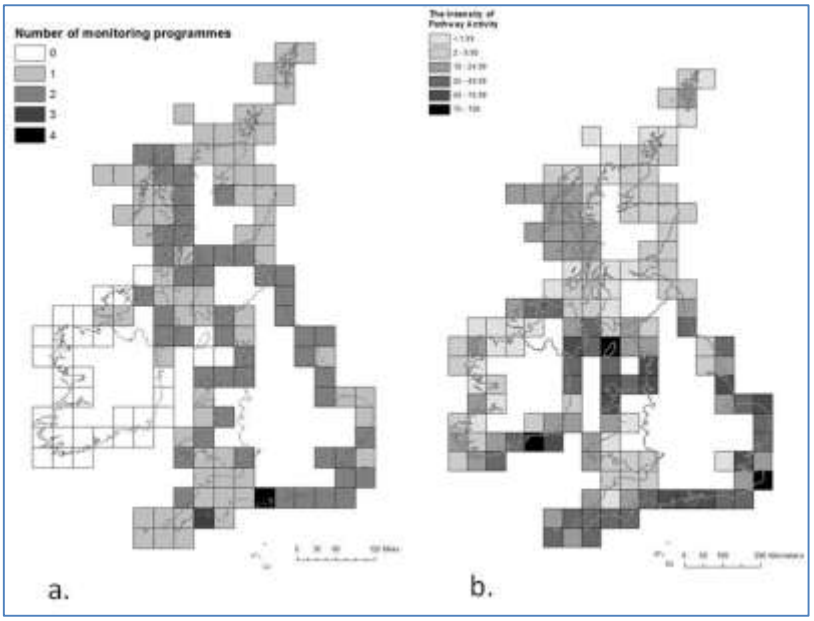

Figure 11. Figure showing a) the total number of monitoring programmes that have sites within 1 NM of the coast in each grid square and b) the potential risk of introduction, indicated by introduction pathway activity, to the grid squares. Please note that only UK monitoring programmes were considered in this report whereas risk of introduction was assessed for both the UK and Republic of Ireland in Tidbury et al (2014).

4.5 Coverage in relation to key NIS

The coverage of current statutory monitoring programmes in relation to the current known distribution of key invasive NIS has been conducted. This can be done by comparing the coverage of monitoring programmes located within 1 NM with the current known distribution of key invasive NIS (see figures 12 -15). The key species selected are the tunicate *Didemnum vexillum*, the Chinese mitten crab *Eriocheir sinensis* and the mollusc *Crepidula fornicata*. It can be seen that the areas where these three species are located are mostly covered by 2 or more monitoring programmes, with the exception of South Wales where *Crepidula fornicata* is present, which is only covered by a single monitoring programme. Although this selection of species does not represent all taxonomic/functional groups they are considered some of the key species and are found in a variety of locations around the UK. The ability of the monitoring programmes to detect a range of NIS has been assessed (see table 3). This table lists NIS species across multiple taxa as examples, however this list is not exhaustive. While the number of monitoring programmes that can detect fish and planktonic species are limited in comparison to epifauna and infauna detection, they would be monitored by some of the most frequent and widely distributed monitoring programmes recommended for us in this report. Eipifaunal and infaunal species are well represented in both in-shore and off-shore monitoring programmes.

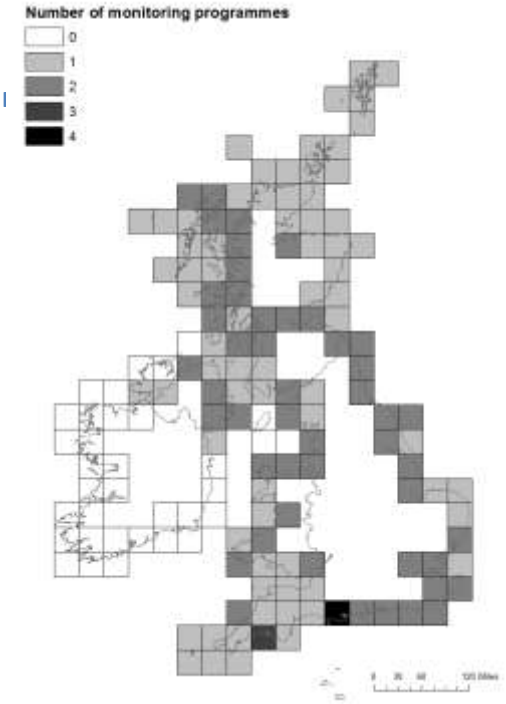

Figure 12. Coverage of monitoring programmes located within 1 nautical mile of the coast. Scores refer to the number of different monitoring programmes for which monitoring may be undertaken in each grid square.

Figure 14. The distribution of *Didemnum vexillum*.

Figure 14. The distribution of *Eriocheir sinensis*

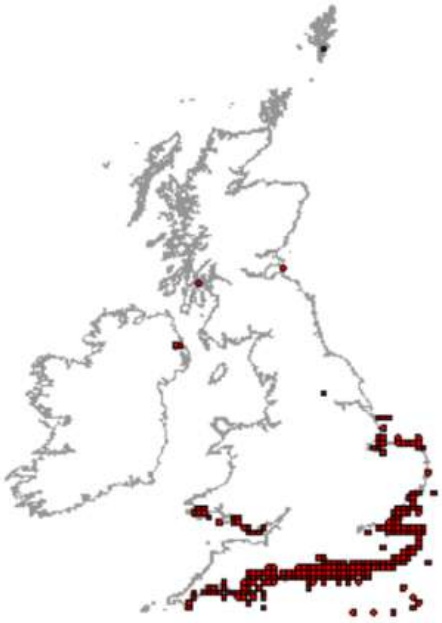

Figure 15. The distribution of *Crepidula fornicata*

Table 3. Potential for monitoring programme to detect NIS using species across multiple taxa as examples. Crosses indicate that there is potential for the monitoring programme to detect the NIS listed.

Group	Example NIS within each ecosystem facet			Potential for monitoring Programmes to detect NIS					
	Genus	Species	common name	CSEMP	Ground fish	SLAB5	WFD	Aggregate	MPA
Fish	*Atherina*	*boyeri*	Big-eyed Sand-smelt	x	x		x		
Epifauna	*Didemnum*	*vexillum*	Carpet Sea-squirt				x	x	x
	Eriocheir	*sinensis*	Chinese Mitten Crab				x	x	x
	Urosalpinx	*cinerea*	American Oyster Drill				x	x	x
	Caprella	*mutica*	Japanese skeleton shrimp				x	x	x
	Crassostrea	*gigas*	Pacific oyster				x	x	x
	Crepidula	*fornicata*	Slipper limpet	x	x	x	x	x	x
	Styela	*clava*	Leathery sea squirt	x	x	x	x	x	x
	Homarus	*americanus*	The American Lobster				x	x	x
	Undaria	*pinnatifida*	Japanese kelp				x	x	x
	Alitta	*succinea*	Pile worm				x	x	x
	Haliplanella	*lineata*	Orange-striped anemone				x	x	x
	Suberites	*massa*	A sponge	x	x	x	x	x	x
	Spartina	*anglica*	Common cordgrass				x	x	x
	Janua	*brasiliensis*	A tube worm				x	x	x
Infauna	*Tapes*	*philippinarum*	Manila clam				x	x	x
	Petricola	*pholadiformis*	American Piddock				x	x	x
	Clymenella	*torquata*	Bamboo worm	x		x	x	x	x
Planktonic	*Odontella*	*sinensis*	Chinese diatom	x			x		

5 Conclusions

Based on the information presented within this report this section provides evidence based advice on the formation of a monitoring and surveillance programme.

5.1 Monitoring programme development

The ability to detect NIS currently present in UK waters has been assessed for all of the non-statutory monitoring programmes presented in section 2. There have been some reports of NIS detected by the statutory monitoring programmes presented in section 3 and there is sufficient evidence to suggest that all of these have the potential to detect NIS (for example see section 7.2 annex 2). However, although the monitoring programmes considered will be able to detect a broad range of taxonomic groups and aid the assessment of the temporal and spatial occurrence of NIS, not all of the programmes will be able to assess the abundance of NIS.

It is likely that information on NIS has been recorded through monitoring programme in the past but due to lack of reporting to GB-NNSIP or the NBN Gateway this information is not accessible and therefore does not facilitate our understanding of the spatial and temporal distribution of NIS in UK waters. So, while there may be limitations associated with the information currently being gathered by monitoring programmes there are also limitations associated with the current management and accessibility of useful data being obtained through these programmes. In view of this, developing a baseline for a monitoring programme would involve gathering and collating crucial up to date information from databases that may contain information of NIS that has not been reported to GB-NNSIP/NBN. The development of a target species list and reporting protocol would greatly enhance detection and reporting of NIS for both statutory and non-statutory monitoring programmes which currently do not Record NIS, despite being within their capability.

While locations at risk of introduction have been identified, this is yet to be conducted for locations at risk from spread. Without identification of locations where spread is likely to occur to and from, the development of a risk based monitoring programme is impossible. As the spatial and temporal distribution of monitoring by current programmes is determined by factors other than locations at risk of spread from NIS, it is impossible to develop a risk based approach to monitoring using currently available survey programmes alone. Ideally for a risk based approach a dedicated monitoring programme would be established where site selection, sampling methodology and frequency can be directly controlled and adapted as required. Despite this, there is still considered to be good coverage

of monitoring programmes within 1 nautical mile using current programmes (see figures 9, 10 and tables 1 and 2). Figures 12-15 compares coverage of the statutory monitoring programmes considered in relation to the known distribution of high impact (ASG working group) NIS. These figures highlight that monitoring occurs in all coastal regions where these species are present. Although it is difficult to assess temporal coverage of the monitoring programmes, the combination of both statutory and non-statutory monitoring programmes is considered to provide sufficient coverage for a monitoring programme. This will, however, require verification, which will only be possible once data is being gathered in relation to MSFD indicators.

While a focus on coastal waters is considered most appropriate for the detection of NIS, the inclusion of off-shore sites is also important to detect certain NIS such as *Crepidula fornicata* and other species often found off-shore. Off-shore monitoring will also provide means to detect the introduction of species via natural dispersal on ocean currents which may utilise off-shore platforms. The detection of species off-shore will also be enhanced by the development of a target species list and reporting protocol.

5.2 Surveillance programme development

The detection of horizon species, especially those that have yet to establish, requires sensitive surveillance techniques. It is not apparent if the monitoring programmes considered as part of this report will be sensitive enough to detect new introductions, however, it should be noted that new introductions (such as that of *Hemigrapsus sanguineus*) have been reported by non-statutory monitoring. Sensitivity of any surveillance programme will be relative to the species in question and its abundance. Until a species list has been developed assessing sensitivity of the current programmes will be impossible.

Assessment of the statutory monitoring programmes considered within this report highlights that there are no sample sites within hotspot locations identified by Tidbury et al (2014) i.e. ports and marinas. Consultancies may occasionally conduct EIAs and similar studies where species composition is reported in ports and marinas. This type of information may be gathered more frequently from locations at high risk of introduction as a result of the BWC exemption procedure, but as this information is gathered for commercial purposes it is rarely widely distributed. Information gathered through this route could constitute valuable records of new NIS. As the spatial and temporal distribution of monitoring by current programmes is determined by factors other than locations at risk of introduction from NIS, it is impossible to develop a risk based approach to surveillance using currently available survey programmes alone. Some non-statutory survey work for NIS has been

conducted in marinas (such as the work conducted by the MBA), but not all of the locations identified as hotspots by Tidbury et al. (2014) have been included in these studies.

In delivery of a risk based surveillance programme for the detection of new NIS, survey work should ideally be conducted at hotspot locations. Hotspot locations have been presented for the UK by Tidbury et al. (2014) based on those sites that fall within the top 25% risk category. It should be noted that the level of risk that is used to define 'high risk' locations can be raised or lowered as seen appropriate. As per evidence presented within Tidbury et al (2014), surveillance, while focused on high risk sites, should also include sites of lower risk. Therefore surveys should also be conducted at lower risk sites but at a lower frequency. For example, at high risk sites, surveys are conducted at a high frequency (e.g. once per annum) and monitoring at locations considered to be of lower risk should be conducted at a reduced frequency (e.g. once every 2-4 years).

5.3 Recommendations

- *The establishment of a baseline from which further monitoring can be assessed*. While the GB-NNSIP and NBN Gateway contains considerable information on marine NIS distribution, additional information is on other data bases. A data mining exercise will allow for the gathering of this information.
- *The development of a target species list.* Given the number of NIS species found in UK marine waters it will be difficult to survey for all of these. The formation of a list of species considered of high importance that monitoring should focus on is recommended. This is similar to the approach adopted under the WFD. This list should not only consist of species currently present within UK waters but those that have been identified as likely to be introduced. Such a species list should ideally be used by both monitoring and surveillance programmes.
- *The remit of statutory monitoring programmes are extended (where required) to include NIS.* While the monitoring programmes assessed within the study have the capacity to detect NIS, there are cases where these are not recorded or reported. Extending the remit of the programmes to include NIS, while not requiring significant additional monitoring effort will require the production of a reporting protocol.
- *Identification procedures to be established for difficult to identify or novel species.* With certain monitoring programmes where identification of species is conducted by experts on site there will be a need for a procedure to deal with difficult to identify or novel species.
- *Identification of a single data repository.* Currently data from statutory monitoring programmes are sent to a number of different data bases. It is recommended that a single

data base where information relating to NIS is identified. This will ensure that all information is gathered and make analysis of data easier.

- *Verification process for monitoring.* It is recommended that a verification process is required to validate the suitability of the current monitoring programmes in the detection of NIS. This will allow for gaps in the monitoring to be identified in addition to ensuring that spatial/temporal coverage and data acquired is sufficient to meet monitoring requirements under the MSFD. This can only be conducted after data has started to be gathered.
- *Establish a risk based surveillance programme at hotspot locations.* Current monitoring programmes do not have sites located in high risk locations. For a risk based surveillance programme to be implanted additional surveillance will be required at high risk sites and lower risk sites at a reduced frequency.

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7 Annexes

7.1 Annex 1. UK marine databases.

Table 4. Table of UK data bases where marine biodiversity information (including NIS) is recorded

Database	Contributors of records	Data Quality Indication	Notes
UNICORN	On the Cefas database: Cefas, JNCC, NE, Marine stakeholders (e.g. wind farm data), Crown Estate, EDF (BEEMS) etc	National quality control scheme provides best practice processing protocol as well as a list of current taxonomic literature. Also run interlab QC audits to ensure data quality from all participating benthic labs.	*Other Gov. agencies use UNICORN also (e.g. EA) and they have their own data holdings. **Some of the data are from industry/provided for use with one project only/restricted.
Marine Recorder	Centre for Environmental Data and Recording (CEDaR, Northern Ireland), Data Archive for Seabed Species and Habitats (DASSH), Joint Nature Conservation Committee, Natural England, Natural Resources Wales, Porcupine Marine Natural History Society, Scottish Natural Heritage, Seasearch (Marine Conservation Society).	Compiled by JNCC	
MEDIN	British Oceanographic Data Centre (for water column oceanography data), British Geological Survey (for geophysical and geological data), DASSH (for marine species and habitats data), UK Hydrographic Office (for bathymetric data), Met Office (for marine meteorological data), Cefas and Marine		Data catalogue for metadata not the data itself. The metadata will inform the searcher if the data is freely accessible and the point of who the point of contact is to obtain the actual dataset.

Database	Contributors of records	Data Quality Indication	Notes
	Scotland (for fisheries data), Archaeology Data Service (for historic environment data)		
Global Biodiversity Information Centre	Contributors include countries, organizations and economies through signature of the Memorandum of Understanding (MoU). Examples include; Endangered Wildlife Trust, Scientific Committee on Antarctic Research (SCAR), NatureServe.	GBIF does not guarantee the accuracy of the biodiversity data served through its portal and web services. Use of data accessed through the portal and web services is at the user's own risk.	
National Biodiversity Network	Many of the UK's wildlife conservation organisations, the government and country agencies, environmental agencies, local records centres and also many voluntary groups.	The NBN Trust has produced best practice advice on Data Verification and Validation. Quality control processes include initial computerisation (and the systems used for this) and subsequent processes such as automated validation	
North Atlantic Register for Marine Species	NW register (Fisheries and Oceans Canada, the Centre for Marine Biodiversity, the Census of Marine Life Gulf of Maine Area Program, Coordinating Research on the North Atlantic (CORONA). European register (MarBEF EU Network of Excellence). European register (MarBEF EU Network of Excellence).		The North Atlantic Register for Marine Species, or NARMS, describes the species biodiversity of the northern North Atlantic Ocean, the Mediterranean, and the Black Sea. It provides up-to-date species registers for both sides of the North Atlantic. The NW list spans diatoms to marine mammals
Ocean Biogeographic Information System	Examples include: Global Biodiversity Information Facility (GBIF), Pacific Biodiversity Information Network (PBIN), Inter-American Biodiversity Information Network (IABIN), Biodiversity Information Standards (Taxonomic Data Working Group, TDWG), Food and Agriculture Organization (FAO).	OBIS Quality Control protocol: the data must pass through a series of technical controls. Any errors, (misspellings, names not recognised in OBIS, and possible mapping errors) are reported to the data provider to review and correct.	The datasets are integrated so you can search them all seamlessly by species name, higher taxonomic level, geographic area, depth, and time; and then map and find environmental data related to the locations.

Database	Contributors of records	Data Quality Indication	Notes
British Oceanographic data centre	Natural Environment Research Council (NERC) projects (marine research in universities and at its own research and collaborative centres).	BODC provide a guide to streamline data submission. They catalogue data standards, file formats and information that should accompany data to ensure their long-term usefulness.	
GB Non-Native Species Information Portal	A range of volunteers, voluntary, statutory bodies (EA, SEPA etc), local records centres, researchers and other organisations.	Data custodians undertake QA, for the marine environment this is the MPA.	Much of this information is passed onto the NBN (see above).

7.2 Annex 2. MPA monitoring case study

Recently collected site verification data (under water video and still images for epifaunal species and benthic grab samples for macroinfaunal species) from MPAs was assessed to determine if MPA monitoring is suitable for and able to detect NIS. Thirty four MPA sites (see figure 16) had a full suite of data including; infauna abundance and biomass (grab data), epifauna presence/absence (video tow data), PSA and metadata (accurate positional information to allow the record to be mapped geographically). These sites included English MCZ's, Scottish MPA's and UK Offshore SAC's (see table 4). One hundred and thirty five species from the GB-NNSIP register were assessed to compile a list of specifically marine species. Epifaunal and infaunal species lists generated from MPA verification surveys were then interrogated. Species data (epifaunal and macroinfaunal) from 34 MPAs were assessed during this study. A total of 425 epifaunal species and 5000 infaunal species were compared with the NNSIP register. Occurrences of NIS were logged and the geographic location of the sample mapped using ARCGIS v10. Additional information on the species count or absence/presence has also been included.

Four genera, *Balanus* (Crustacean), *Hydroides* (polychaete), *Suberites* (sponge), *Bugula* (Bryozoan), were identified as possible matches to the NNSIP register. Nine marine NIS currently on the NNSIP register were identified from the infaunal species list compiled from the current MPA data holdings. These included the polychaete worms *Clymenella cincta*, *Goniadella gracilis*, *Hydroides elegans*., *Metavermilla multicristata* and *Vermiliopsis striaticeps*, the ascidian *Styela clava*, the Molluscs *Crepidula fornicata* and *Mya arenia*, and the crustacean *Eusarsiella zostericola*.

Goniadella gracilis had the highest number of records (present at 9 of the 34 surveyed sites) and was widely distributed throughout UK waters from the North East at Turbot Bank to the South West in the South East Falmouth rMCZ. Both Bugula and *Crepidula fornicata* were located in sites on the South East coast and *Vermiliopsis striaticeps* and Suberites were found in the South West. Records for hydroides and *Hydroides elegans* were both found located on the west coast of the UK.

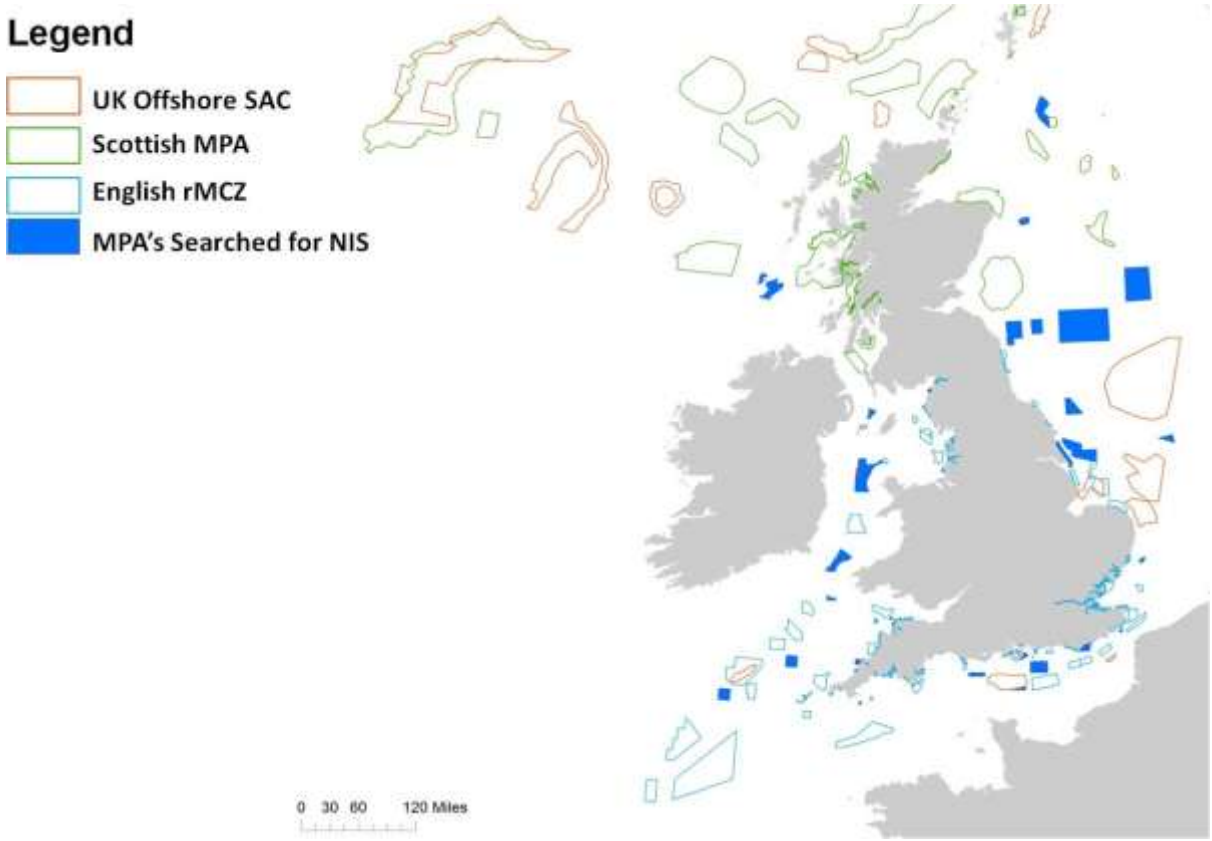

Figure 16. Map showing the MPA areas (English MCZ, Scottish MPA and UK Offshore SAC) assessed to determine if monitoring is suitable for and able to detect NIS.

Table 5. Table of the MPA sites assessed for the presence of NIS and where NIS were found.

MPA Designation	Site Name	Sites where NIS were present
English rMCZ	Allonby Bay	✓
	Beachy Head East	✓
	Bembridge	✓
	Compass Rose	
	East Celtic Deep	
	East Haig Fras	✓
	Farne East	✓
	Folkstone Pomerania	✓
	Fulmar	
	Holderness Inshore	✓
	Holderness Offshore	
	Markhams Triangle	
	Morte Platform	✓
	Mounts Bay	
	North Celtic Deep	✓
	North St Georges Channel	
	North West Jones Bank	✓
	Offshore Overfalls	
	Orford Inshore	
	Padstow Bay and Surrounds	✓
	Rock Unique	✓
	South Dorset	✓
	South East Falmouth	✓
	South Rigg	✓
	Swallow Sands	✓
	The Manacles	✓
	Wight Barfleur	
UK Offshore SAC	Stanton Banks	
	Scanner Pockmarks	
	Braemar Pockmarks	
	Bassurelle Sandbank	
Scottish MPA	Central Fladen	
	Western Fladen	
	Turbot Bank	✓

Table 6. Occurrence of non-native species in the selected MPA site.

	Clymenella cincta	*Crepidula fornicata*	*Eusarsiella zostericola*	*Goniadella gracilis*	*Hydroides elegans*	Hydroides	*Metavermilia multicristata*	*Mya arenaria*	*Styela clava*	*Vermiliopsis striaticeps*	Balanus	Bugula	Suberites
Allonby Bay											✓		
Bembridge	✓	✓										✓	
Beachy Head East		✓										✓	
East Haig Fras				✓									
Farne East	✓			✓									
Folkstone Pomerania		✓											
Holderness Inshore								✓					
Morte Platform										✓			
North Celtic Deep				✓		✓	✓						
North West Jones Bank				✓									
Padstow Bay				✓									
Rock Unique				✓				✓					
South dorset									✓				
South East Falmouth				✓									
Swallow Sand				✓									
South Rigg					✓								
The Manacles										✓			✓
Turbot Bank				✓							✓		
Wight Barfleur			✓										

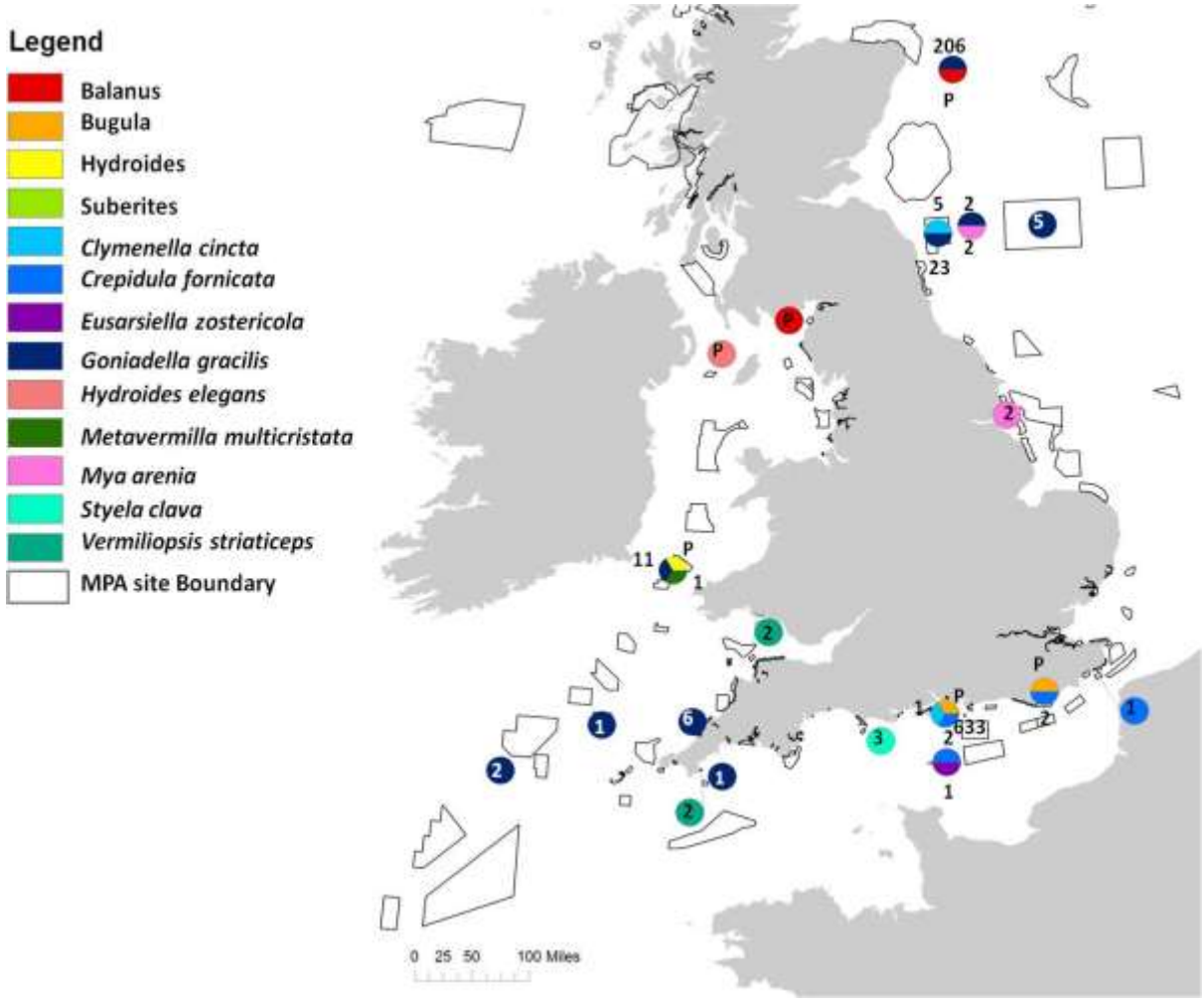

Figure 17. Location map of the occurrences of NIS genera/species; Balanus, Bugula, Hydroides, Suberites, *Clymenella cincta*, *Goniadella gracilis*, *Hydroides elegans*, *Metavermilla multicristata*, *Vermiliopsis striaticeps*, *Styela clava*, *Crepidula fornicata*, *Mya arenia*, *Eusarsiella zostericola* at rMCZ sites in England and MPA sites in Scotland. Abundance (species count from grab data) of each genera/species is shown inside or adjacent to its corresponding chart. 'P' indicates presence of the genera from video tow data.

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