Cyfoeth Naturiol Cymru
Natural Resources Wales

Review of Monitoring of Marine Non-native Species in Great Britain and Evaluation of Gaps in Data Dissemination

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Report No. 20.

About Natural Resources Wales

Natural Resources Wales is the organisation responsible for the work carried out by the three former organisations, the Countryside Council for Wales, Environment Agency Wales and Forestry Commission Wales. It is also responsible for some functions previously undertaken by Welsh Government.

Our purpose is to ensure that the natural resources of Wales are sustainably maintained, used and enhanced, now and in the future.

We work for the communities of Wales to protect people and their homes as much as possible from environmental incidents like flooding and pollution. We provide opportunities for people to learn, use and benefit from Wales' natural resources.

We work to support Wales' economy by enabling the sustainable use of natural resources to support jobs and enterprise. We help businesses and developers to understand and consider environmental limits when they make important decisions.

We work to maintain and improve the quality of the environment for everyone and we work towards making the environment and our natural resources more resilient to climate change and other pressures.

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- Maintaining and developing the technical specialist skills of our staff;
- Securing our data and information;
- Having a well resourced proactive programme of evidence work;
- Continuing to review and add to our evidence to ensure it is fit for the challenges facing us; and
- Communicating our evidence in an open and transparent way.

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1. Crynodeb Gweithredol

Mae rhywogaethau estron, sef organeddau sydd wedi symud y tu allan i'w cynefin naturiol trwy gael eu cyflwyno naill ai'n fwriadol neu'n anfwriadol, wedi dod yn bryder cynyddol mewn blynyddoedd diweddar oherwydd yr effaith ecolegol negyddol y gallent ei chael, yn ogystal â'r niwed economaidd. Mae'r awydd i ymdrin â'r problemau sy'n gysylltiedig â rhywogaethau estron wedi dwysáu, gan arwain at nifer o bolisïau diweddar ar lefel yr Undeb Ewropeaidd a Phrydain Fawr sydd â'r nod o gadw ymlediad rhywogaethau o'r fath dan reolaeth. Mae mentrau diweddar yn hyrwyddo'r arfer o roi rhaglenni monitro trylwyr ar waith yn amgylchedd y môr, fel y gellir canfod rhywogaethau estron yn gynnar. Dim ond trwy ddod o hyd i'r rhywogaethau hyn yn gynnar y ceir unrhyw bosibilrwydd o'u rheoli'n lleol ac, o bosibl, eu dileu.

Nod yr arolwg hwn oedd pwyso a mesur statws gweithgareddau monitro ar gyfer rhywogaethau estron morol, nodi ffynonellau data hollbwysig o'r fath a nodi unrhyw fylchau yn y ffordd rydym yn rhannu data. Er mwyn cael gafael ar yr wybodaeth hon, rhoddwyd nifer o ddulliau ar waith. Adolygwyd llenyddiaeth wyddonol trwy ddefnyddio *Web of Knowledge*, a chymharwyd cofnodion â'r rheini a geir ym Mhorth y Rhwydwaith Bioamrywiaeth Cenedlaethol, sef ystorfa ganolog yn ymwneud â dosbarthiad yr holl rywogaethau a geir ym Mhrydain Fawr. Yna, aethpwyd ati i gymharu data Porth y Rhwydwaith Bioamrywiaeth Cenedlaethol â'r cyhoeddiad mwyaf diweddar sy'n cynnwys rhestr lawn o rywogaethau estron morol ar gyfer Prydain Fawr (Minchin et al. 2013) er mwyn canfod unrhyw fylchau yn y cofnodion. Ymhellach, aethpwyd ati i werthuso'r cofnodion a geir ym Mhorth y Rhwydwaith Bioamrywiaeth Cenedlaethol er mwyn deall y ffynonellau data hollbwysig sy'n ymwneud â dosbarthiad rhywogaethau estron morol a pha sefydliadau a oedd yn gyfrifol am gyfrannu llawer o ddata, gyda chanolbwynt ychwanegol ar Gymru.

Mae nifer fawr o ddata'n cael ei gasglu am rywogaethau estron morol o amrywiaeth eang o ffynonellau. Mae'r adolygiad hwn yn dangos bod sefydliadau sy'n defnyddio gwyddonwyr dinesig trwy gyfrwng rhaglenni gwirfoddol, fel prosiect *Seasearch* y *Marine Conservation Society*, yn bwysig o safbwynt cyfrannu data am rywogaethau estron morol. Mae gan ymgyrchoedd fel y rhain y potensial o gynorthwyo gydag ymdrechion monitro yn y dyfodol a helpu i wireddu ymrwymiadau'r Undeb Ewropeaidd. Daethpwyd o hyd i nifer o fylchau o safbwynt rhywogaethau estron morol nad oeddynt wedi'u cofnodi ar Borth y Rhwydwaith Bioamrywiaeth Cenedlaethol, er bod cyhoeddiadau i'w cael a oedd yn crybwyll poblogaethau sefydledig ar eu cyfer.

2. Executive Summary

Non-native species (NNS), those organisms which have moved outside of their natural range either through inadvertent or deliberate introduction, have become an increasing concern in recent years due to the potential for negative ecological impacts as well as economic damage. Momentum has been growing to address the issues associated with non-native species, culminating in a number of recent policies at EU and GB-level to curb the upward trend of invasions. Recent initiatives advocate the adoption of robust monitoring programmes in the marine environment to enable the early detection of non-native species. It is only through early detection that there is likely to be any possibility of local control and potential eradication.

The objective of this review was to evaluate the status of monitoring activity for marine non-native species, identifying the key sources of such data and any gaps in the way data is shared. To obtain this information, a number of approaches were adopted. A review of the scientific literature was conducted using Web of Knowledge, and records compared to those contained with the National Biodiversity Network (NBN) Gateway, a central repository for distribution data on all species found in Great Britain (GB). Data on the NBN Gateway was then compared to the most recent publication containing a full marine non-native species list for GB (Minchin et al. 2013) to identify any gaps in the records. In addition, records in the NBN Gateway were evaluated to understand the key sources of distribution data on marine non-native species and which organisations were responsible for contributing large volumes of data, with an additional focus on Wales.

Significant amounts of data are being collected on marine non-native species from a wide range of sources. The review shows that organisations engaging citizen scientists through volunteer programmes, such as the Marine Conservation Society's Seasearch Project, are important contributors of marine non-native species data. Campaigns such as these have the potential to assist with future monitoring efforts and help meet EU commitments. A number of gaps were identified in terms of marine non-native species with no records on the NBN Gateway despite publications indicating established populations.

3. Introduction

Non-native species, organisms which have overcome dispersal and geographical barriers to establish in regions outside of their natural range, are an increasing occurrence in the marine environment due to rapidly expanding trade and transportation networks (Eno 1996, Pyšek et al. 2008, Blakeslee et al. 2011). Some non-natives, once established, make little difference to their novel environment, although others can become invasive causing ecological and economic problems. Evidence of the detrimental impacts caused by non-native species is increasing (Williamson & Fitter 1996, Bax et al. 2003, Rius et al. 2011).

Marine non-native species are often difficult to detect until they attain a large population size, creating significant challenges in relation to controlling or eradicating these populations. The Convention on Biological Diversity (COP 6 Decision VI/23) recommends a three-stage hierarchical approach to minimise the impact and spread of non-native species: i) prevention; ii) early detection and rapid response; iii) containment and long-term control. This overarching approach has been adopted by many signatory nations, including the United Kingdom (CBD 2002). Although preventing the arrival of non-native species in the first instance is universally agreed as the preferred mechanism by which to manage non-native species, the open nature of the marine environment means that even nations with robust biosecurity protocols are unable to wholly prevent marine incursions (McEnnulty et al. 2001, Meyerson & Reaser 2002).

As concerns grow around the effects of non-native species on native ecosystems and economic assets, greater emphasis is being placed on the development of effective early warning systems to identify non-natives at the early stages of invasion. The recently published draft EU Regulation on Invasive Alien Species (EC 2013) stipulates in Chapter III that Member States should have implemented surveillance and reporting schemes for invasive alien species within 18-months of the Regulation entering into force. In addition, the EU Marine Strategy Framework Directive (EC 2008) has a specific descriptor pertaining to marine non-indigenous species which states that these organisms should not attain levels that result in adverse effects on native ecosystems. Within this descriptor, Member States are required to implement monitoring programmes by mid-2014. At a GB-level, the Invasive Non-Native Species Framework Strategy for Great Britain (2008) sets out high-level objectives for monitoring non-native species and an updated strategy document is due for publication during 2014.

Reviewing the status of monitoring of marine non-native species, is a valuable and timely activity in light of the pressing need to develop formalised monitoring programmes for non-native species in Great Britain. By understanding what monitoring has already been conducted, where, when and by whom, it may help to inform future monitoring programme design and identify gaps in the way data is disseminated and shared within a GB-context.

Therefore, the objectives of this review were to:

- Review the scientific literature to identify monitoring activity targeting marine non-native species.

- Examine publicly accessible biodiversity repositories to understand the key providers of primary data on the distribution of marine non-native species.
- Identify gaps in data dissemination on marine non-native species.

4. Scientific Literature Search Using Web of Knowledge

An extensive query using the Web of Knowledge database was run to identify any literature relating to monitoring or surveillance work targeting marine non-native species covering England, Ireland, Scotland and Wales (see Appendix A for list of search terms). Of the 289 articles returned by the query, 44 were relevant to marine non-native species monitoring and examined in more detail (see Appendix B). For each article, the following information was extracted where available:

- Year of publication
- Aims of the study
- Methods employed
- Funding source
- Geographical location
- Type of study site
- Data available on NBN Gateway

It should be noted that further literature may be published relating to the monitoring of non-native species in the marine environment that was not identified using the search terms employed in the Web of Knowledge query. Ireland was included in the search due to the close collaborative efforts between the UK and Ireland on the subject of marine non-native species.

4.1. Year of Publication

Since 2004, a steady stream of publications has been published annually in the UK and Ireland containing location-specific information on marine non-native species (Fig 1).

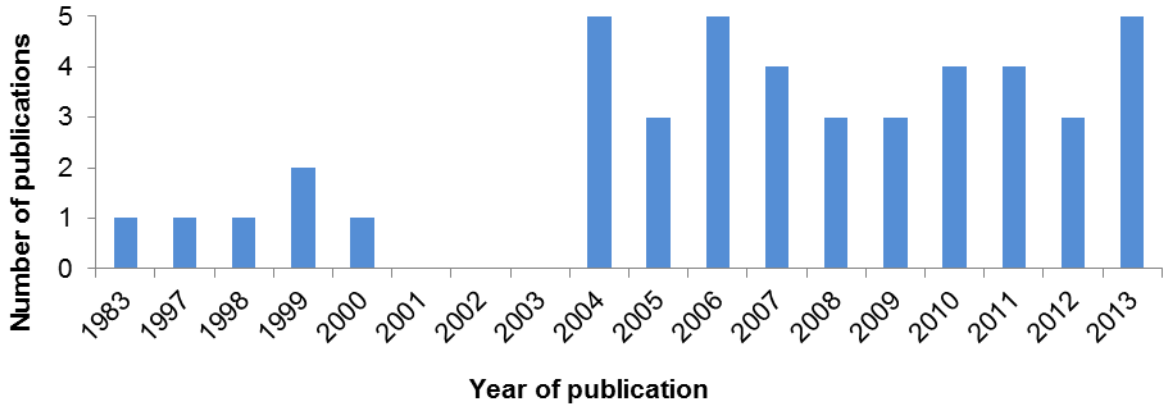

Figure 1. Scientific Literature by Year of Publication.

4.2. Methods

Several approaches have been adopted to collect data on marine non-native species around the UK and Ireland. Ten studies employed rapid assessment surveys which are surveys conducted over a finite period of time (1-2 hours) by a team of taxonomic experts capable of identifying the majority of target species in-situ. This approach was predominantly used in marinas and harbours, known hotspots for marine non-native species, but was also used at fish farms with floating pontoons and on an intertidal rocky shore. The rapid assessment survey technique was used in three ways: single species; targeted lists of non-native species; and to record native and non-native species. Most of the studies using rapid assessment surveys looked at multiple locations helping to generate a significant amount of baseline data within a short period of time. Studies of subtidal environments used dredging, core sampling and beam trawl techniques with three studies using scuba divers or snorkelers to collect data. Three studies used settlement panels. Rocky shore surveys were mostly conducted using a combination of quadrats and transects over short distances. The majority of studies collected samples for further analysis and to confirm taxonomic identity. Six of the studies did not collect primary data, instead employing literature searches to review information available on the distribution or spread of a species.

4.3. Geographic Location and Type of Study Site

England has to date, based on the 44 publications found through the Web of Knowledge literature search, the largest volume of literature relating to marine non-native species (Fig. 2), however there is a clear bias towards the south coast, with little coverage of other parts of the English coastline. Evidence from the literature shows that all nations have conducted rapid assessment surveys of marinas and harbours which are considered high-risk sites; however, there is no evidence from the literature search that these surveys have been repeated.

Figure 2. Publication by Country of Study.

Harbours and marinas have been the sites of highest intensity survey work to date (Fig. 3), with several studies covering upwards of ten marinas and multiple species providing a useful baseline to build upon as part of the UK's commitment to implementing monitoring programmes for non-native species. Estuaries and loughs were the second most studied site type, although at these localities, only single species were investigated. Collectively, sites of known high levels of anthropogenic disturbance such as marinas, aquaculture sites and estuaries have been more extensively surveyed than rocky shores from the evidence presented in the scientific literature search. Subtidal environments are the least studied, possibly due to high costs associated with working underwater or lower priority due to the more natural environmental setting.

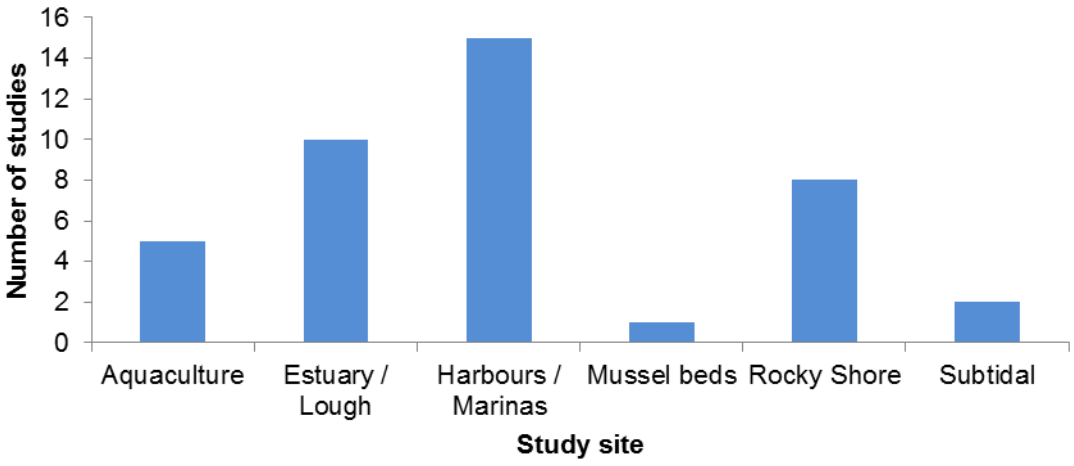

Figure 3. Types of Sites used in Study.

4.4. Type of Study

The majority of studies included in this review focused on examining the distribution of a single species (Fig 4). Many of the target species are known to have the potential to have negative environmental or economic effects.

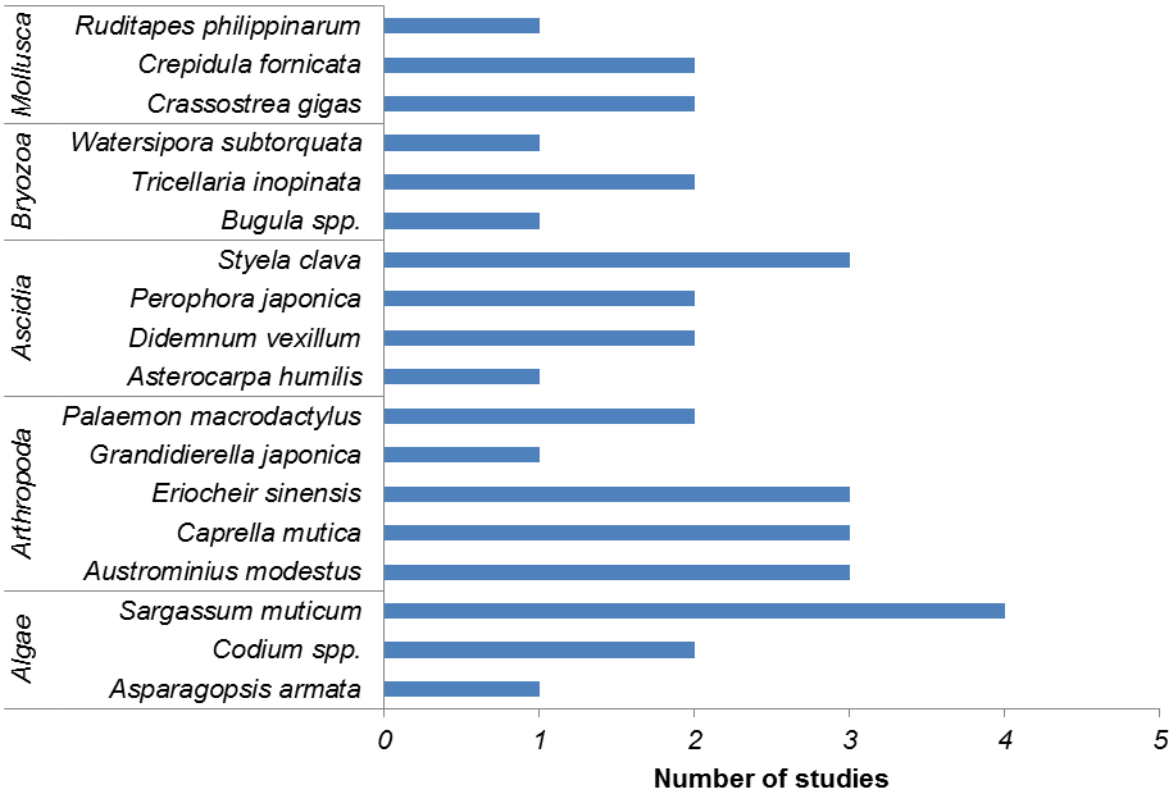

Figure 4. Single Species Studies by Species.

Published studies describing the distribution of multiple non-native species were limited to three rapid assessment surveys (RAS) (Arenas *et al*. 2006, Ashton *et al*. 2006, Minchin 2007). The study by Arenas *et al*. (2006) made a general assessment of non-native and native species whereas the other two RAS studies tailored their search time to look for non-native species in particular. Ashton et al. (2006) used their search time to target the seven target species studied in the Marine Aliens I programme and Minchin (2007) searched for 20 non-native species which targeted species known to be present in Ireland, and those not yet established but with the potential to have arrived. The ascidians *Styela clava* and *Perophora japonica*, the crustacean *Caprella mutica* and the macroalgae *Undaria pinnatifida* and *Sargassum muticum* were either searched for or recorded in all three studies (Fig. 5). These three surveys were conducted between 2004 and 2006, with no indication from the scientific literature to show that repeat surveys have been conducted but evidence may exist in other forms not detected through the literature search.

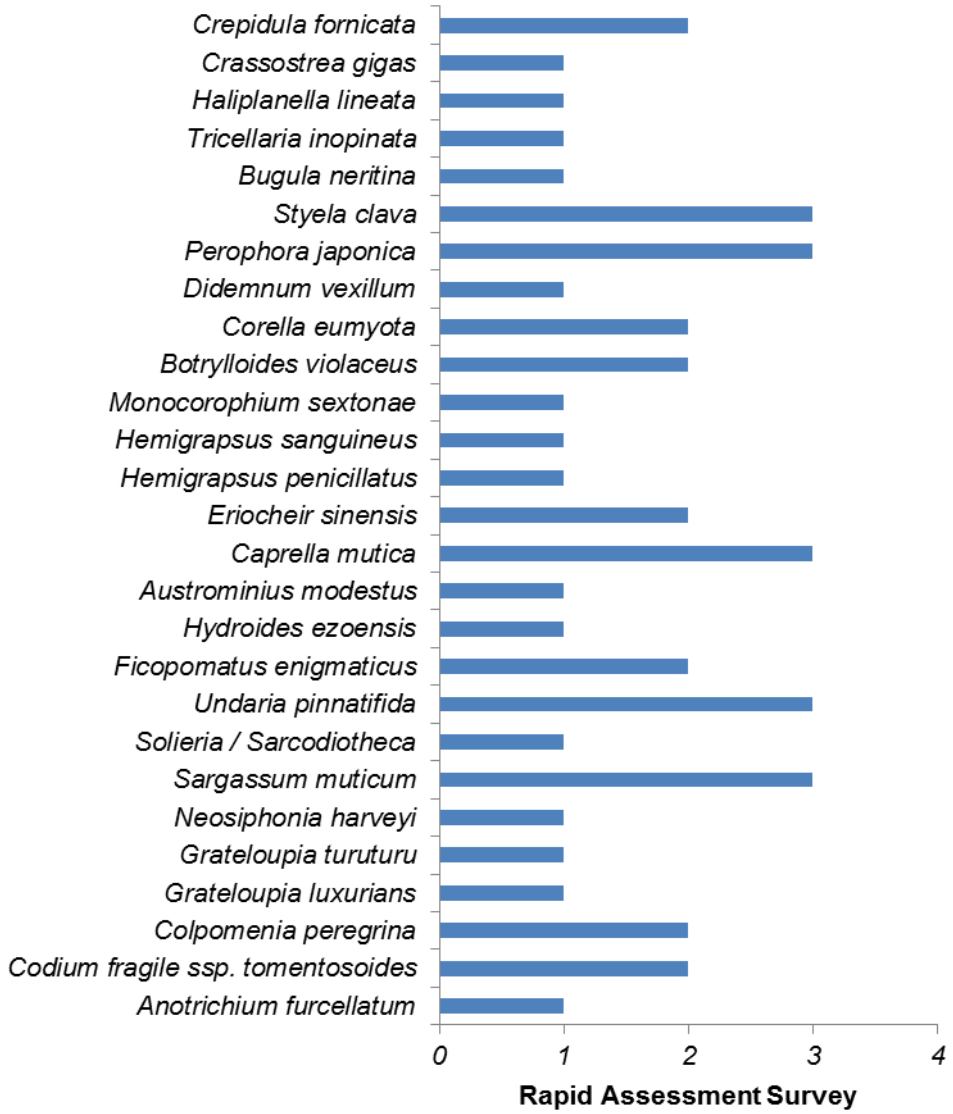

Figure 5. Non-native species recorded during three rapid assessment surveys (Arenas et al. 2006, Ashton et al. 2006, Minchin, 2007).

4.5. Funding Source

Sources of funding were diverse, from local organisations to international bodies although international support was predominantly from academic institutions sponsoring students. The Esmeé Fairbairn Foundation supported the highest number of publications through its funding of the Marine Aliens I and II programmes (see section 3 for more details).

Table 1. Funding Sources from Scientific Literature.

Funding source	Number of studies
Not mentioned	11
Esmeé Fairbairn Foundation	9
Natural Environment Research Council	8
EU ALARM (Assessing large-scale risks to biodiversity using tested methods)	4
EU DAISIE (Delivering Alien Invasive Species Inventories for Europe)	4
AXA Research Fund Marine Aliens & Climate Change	3
National Science Foundation Grant	3
British Ecological Society	2
Department of the Environment, Northern Ireland	2
Environment Agency	2
Interreg IVa Marinexus	2
Natural England (previously English Nature)	2
Aggregate Levy Sustainability Fund	1
Agri-Food & Biosciences Institute	1
Australian Research Council Grant	1
Bangor Mussel Producers	1
Brazilian Ministry of Education	1
Department of Agriculture & Rural Development	1
EU Framework Project 6 Network of Excellence 'Marine Genomics'	1
EU Project ALIENS (Algal Introductions into European Shores)	1
EU VECTORS (Vectors of Change in Oceans and Seas Marine Life, Impact on Economic Sectors).	1
Harwich Haven Authority	1
Heritage Council (Ireland)	1
Irish Environmental Protection Agency	1
Irish Research Council for Science, Engineering & Technology	1
Irish Research Council for the Humanities & Social Sciences	1
Joint Nature Conservancy Council (JNCC)	1
Ministry of Science, Spanish Government	1
Natural Resources Wales (previously CCW)	1
National University Ireland Galway's Millennium Fund	1
Royal Society	1
Scottish Natural Heritage	1
University of Newcastle	1

4.6. Data on National Biodiversity Network (NBN) Gateway

The NBN Gateway is a central repository for species distribution data in the United Kingdom where government and country agencies, environmental agencies, local records centres and also many voluntary groups are responsible for sharing and maintaining their biodiversity datasets. The Great Britain Non-Native Species Secretariat (GBNNSS) website extracts data from the NBN Gateway to populate its distribution maps on non-native species so keeping this source of data current and reliable is essential for monitoring marine non-native species distribution and understanding rates of spread. During the review of the scientific literature, it has become apparent that data collected for many of these studies has not been inputted onto the NBN Gateway. In fact, several of the species covered within the studies do not appear on the NBN Gateway at all.

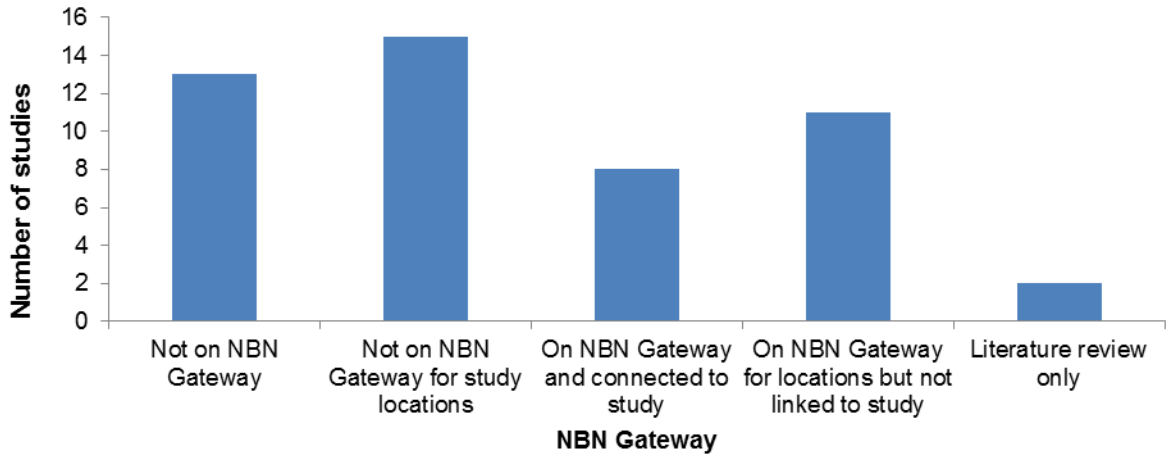

Figure 6. Scientific literature and NBN Gateway distribution data (Not on NBN Gateway = no records exist for target species; Not on NBN Gateway for study locations = records exist but not for study areas; On NBN Gateway and connected to study = where author or agency noted as recorder of data and locations match records; On NBN Gateway for locations but not linked to study = records exist on NBN Gateway but correlation with study unclear i.e. dates, organisation or authors don't correlate; Literature review only = insufficient detail on distribution).

Marine non-native species whose presence was recorded in the scientific literature but have no distribution records entered for the UK on the NBN Gateway were *Palaemon macrodactylus* (Ashelby *et al*. 2004, *Worsfold & Ashelby* 2006, *Didemnum vexillum* (Griffith *et al.* 2009, Beveridge *et al.* 2011), *Asterocarpa humilis* (Bishop *et al.* 2013), *Ostrea chilensis* (Eno *et al*. 1997, Minchin *et al*. 2013), *Neosiphonia harveyi* (Mineur *et al.* 2008), and *Heterosiphonia japonica* (Beveridge *et al.* 2011). The NBN record for *Tricellaria inopinata* indicates there are ten entries on the NBN Gateway but these are not visible either through datasets or the interactive map so users are not able to view the location of those records, when they were recorded and by whom (Johnston *et al.* 2011, Kelso & Jackson 2012, Cook *et al.* 2013). *Caprella mutica* is reported in Scotland in a number of the publications reviewed, yet does not appear on the NBN Gateway in any locality in Scotland. In addition, *Corella eumyota* records have not been entered for Scotland (Beveridge *et al.* 2011). *Botrylloides violaceus* was reported on the GB mainland within the literature but no records appear on NBN Gateway (Arenas *et al*. 2006, Johnston *et al.* 2011).

4.7. Follow Up Activity

There is limited evidence of any follow up action after the initial study or that the study contributed to, or was part of, a regular monitoring programme, although there were a couple of positive examples. Ashelby *et al.* (2004) found the non-native prawn *Palaemon macrodactylus* during a regular monitoring programme to assess fish and shrimp populations in the Orwell estuary which led to follow up activity in the Greater Thames area, examining preserved specimens from other studies which resulted in further evidence that populations may be established. In addition, Beveridge *et al.* (2011) initiated surveys for *Didemnum vexillum* in Scotland following the finding of this species in Wales (Griffith *et al.* 2009), which was the first record in Britain. Many of the publications made recommendations for future work which often included additional monitoring activities, particularly when new species were recorded in a locality. Although action based on these recommendations appears limited, follow up action may have been instigated by regional conservation or environmental bodies that may not have been picked up through this type of literature search. In the case of the *D. vexillum* incursion in Wales for example, an annual monitoring programme of high risk marinas has been instigated and led by Natural Resources Wales, the statutory body responsible for nature conservation in Wales.

RECOMMENDATIONS

- Awareness raising / training for authors of scientific literature to encourage them to input distribution data into NBN Gateway. This is valuable information, which is currently being lost, which could assist with understanding where marine non-natives are spreading and the rate of spread.
- Those species with no records on the NBN Gateway but with a known presence in the UK should be added to provide a more complete picture of marine non-native distribution.
- Encourage greater use of the absence option for recording species on the NBN Gateway to demonstrate when NNS have been searched for but not found.

5. Marine Aliens I and II Work Programmes

The Marine Aliens programme, funded primarily through the Esmeé Fairbairn Foundation, was the first significant piece of work to raise the profile of marine non-native species in the UK and Ireland. Marine Aliens I, which ran from 2004-2007 focused on seven target non-native species (*Caprella mutica*, *Codium fragile* ssp. *tomentosoides*, *Eriocheir sinensis*, *Perophora japonica*, *Sargassum muticum*, *Styela clava* and *Undaria pinnatifida*) to understand the distribution, spread, biology, ecological impacts and mechanisms of invasion for these species. As part of this work, distribution maps were produced for the seven target species which were subsequently posted on the Marine Aliens website, shared with the EU initiative DAISIE and linked with the MarLIN website. However, the distribution data collated through this work does not appear to have been placed on the NBN Gateway which may explain why *Caprella mutica* is currently not recorded for Scotland.
Marine Aliens II, which ran from 2008-2011, concentrated on examining vectors of dispersal such as hull fouling. In addition, one of the key objectives of the

programme was to identify the most effective methods to detect new arrivals of marine non-native species. This objective was refined to look at developing a monitoring system for ports, marinas and vessel hulls that could be employed by non-specialist staff and volunteers. Correx settlement panels were trialled, and have continued to be used by Cornwall Wildlife Trust to engage citizen scientists with the collection of information on marine non-native species. Identification guides were also produced as part of the programme and are available from the MarLIN Marine Aliens website. Rapid assessment surveys were carried out, with particular focus on Didemnum vexillum following its discovery in Wales during 2008. 36 marinas along the south coast of England were surveyed as well as marinas in Scotland, commissioned by Defra and Scottish Natural Heritage. The surveys found additional non-native species such as *Watersipora subtorquata* and *Botrylloides violaceus* (neither recorded on NBN Gateway for locations mentioned). Sites in north-east England were also surveyed as part of this programme of work during 2010, with only the non-native barnacle *Austrominius modestus* recorded. In addition, the final report refers to the Marine Biodiversity & Climate Change project (MarClim/MBA) which has been collecting distribution and abundance data annually on non-native species at long-term time series sites in England, Scotland and Wales. The final reports for Marine Aliens I and II provide more detail on publications produced.

RECOMMENDATIONS

- Data collected through the Marine Aliens I and II programs should be inputted into the NBN Gateway, ideally as a single Marine Aliens dataset to allow for traceability of the data

6. Great Britain Non-Native Species Secretariat (GBNNSS) Portal

The Great Britain Non-Native Species Secretariat is responsible for co-ordinating the management approach to non-native species and disseminating good practice and guidance to support individuals and organisations in addressing non-native species issues. The website (http://www.nonnativespecies.org/home/index.cfm) uses data from the NBN Gateway to provide distribution maps. The portal has a section specifically for non-native species projects which aims to display information on work from local action group projects up to nationwide surveys. This area appears to be either currently underutilised or indicative of a lack of monitoring effort in the marine environment, as there are few projects of marine relevance. Within the category 'Monitoring/Survey', of the 32 current projects [accessed 19/01/14], none explicitly refer to marine non-native species, although three projects report monitoring efforts on the Chinese Mitten Crab, *Eriocheir sinensis*. In total there are 116 projects listed (past and present) under the 'Monitoring/Survey' category, of which 11 encompass some element of marine monitoring (Table 2). Having a centralised source for information on marine non-native species monitoring projects provides a valuable knowledge sharing tool that if optimally used, could assist with meeting EU-level commitments in relation to monitoring of marine non-native species.

RECOMMENDATIONS

- Awareness raising of the GBNNSS Projects Database section required to encourage those involved in marine non-native initiatives to publish and maintain information on projects on the GBNNSS portal http://www.nonnativespecies.org/maps/index.cfm.

- Additional category could be added to the GBNNSS Projects Database search engine to enable users to search for Marine, Freshwater or Terrestrial projects.

Table 2. Past and current projects listed on GBNNSS portal relating to marine NNS monitoring/survey work.

Project	Species	Status
Manx Biological Database and Information System	All species	Ongoing
Environment Agency – Mitten Crabs	*Eriocheir sinensis*	Completed
Sargassum muticum PhD – University of Glamorgan	*Sargassum muticum*	Completed
Shorething – non-native species project	*Sargassum muticum* *Undaria pinnatifida* *Codium fragile* *Asparagopsis armata* *Colpomenia peregrina* *Crepidula fornicata* *Styela clava* *Crassostrea gigas* *Austrominius modestus*	Completed
Recording Invasive Species Counts (RISC)	*Eriocheir sinensis*	Completed
Investigate Invasives – Marine, Cornwall Wildlife Trust	Invasive non-native marine fouling organisms	Completed
Assessing the risk of transporting non-native species to Scotland via biofouling on vessels	Any native or non-native species on vessel hulls	Completed
Lancashire Invasive Species Project	*Eriocheir sinensis*	Ongoing
Yorkshire INNS and Biosecurity Forum	*Eriocheir sinensis*	Ongoing
Shetland Non-Native Marine Species Project	Not mentioned	Completed
Mitten Crabs and Signal Crayfish – Impacts and Interactions, University of Leeds	*Eriocheir sinensis*	Ongoing

7. National Biodiversity Network (NBN) Gateway Analysis

Data on biodiversity are collected from a wide range of sources, from individuals to government bodies to conservation organisations and many more. The NBN Gateway encourages those involved in the collection of species information to input their data in a standardised format onto the NBN Gateway. These data are then usually made publicly accessible although some datasets on sensitive species and habitats can be restricted. A central source of species distribution data is particularly valuable in gathering together information on non-native species from disparate sources and can provide information on who are the key providers of non-native species distribution data and how frequently data are collected.

To determine the key providers of distribution data on marine non-native species, the NBN Gateway was searched for marine non-native species currently listed as established in Britain by Minchin *et al.* (2013). These established NNS were searched for individually within the NBN Gateway to:

- Check that all species listed as established have records on the NBN Gateway
- Examine the sources of data on marine non-native species
- Evaluate which providers are supplying significant amounts of distribution records on marine non-native species.

7.1. Established species

Of the 58 species classified as established in Minchin *et al.* (2013), 12 have no distribution information published on the NBN Gateway, although this could be partially attributed to some records being restricted (Table 3).

Table 3. Established species from Minchin *et al.* (2013) with no records in NBN Gateway.

Species	Status according to Minchin et al. (2013)	Comments
Acartia tonsa	Regionally, established	
Anguillicoloides crassus	Widespread, established	Parasitic nematode worm found in eels. Distribution data not feasible
Bonamia ostreae	Widespread, established	Parasitic protist found in shellfish, particularly oysters. Distribution data not feasible
Botrylloides c.f. diegensis	Localities, established	
Didemnum vexillum	Regionally, established	
Gonionemus vertens	Widespread, established	
Heterosiphonia japonica	Widespread, established	
Palaemon macrodactylus	Localities, established	
Pileolaria berkeleyana	Localities, established	
Rhithropanopeus harrisii	One locality, established	
Ostrea chilensis	One locality, established	On NBN Gateway as *Tiostrea lutaria* but still no records
Tricellaria inopinata	Regionally, established	NBN Gateway suggests ten records but unable to access
Watersipora subtorquata	Localities, established	

In addition, two species listed as ‘not established’ do have recent records in the NBN Gateway:

- *Crassostrea virginica*: records from 1993 – 2006 for Anglesey, Wales.
- *Hydroides elegans*: records from several locations from 1990 to most recent records in Scotland from 2010.

Although the data on NBN Gateway does not indicate whether these species should be classified as established, it does highlight the potential value of using the NBN Gateway in addition to scientific literature searches to obtain distribution data on marine non-native species.

7.2. Sources of Data on Marine Non-native Species

Of 927 datasets [accessed 19/01/14] in the NBN Gateway, 28 explicitly contain the terms non-native or invasive in the dataset title, covering terrestrial, freshwater and marine species. Of the 28 datasets focused on non-native or invasive species, eight include data on marine species:

- Marine Science Project - Citizen Science Settlement Panels. Data of both native and non-native fouling species detected on settlement panels deployed in Cornwall during 2012.
- Norfolk Non Native Species Records.
- RISC and ALERT Marine Non-Native Species (Chinese Mitten Crab, Wakame and Carpet Sea Squirt) Records.
- Environment Agency Non-native Species records v1.
- Invasive non-native species in Kent: records from 1900 to March 201.2
- Invasive Non-Native Species (INNS) Devon.
- HBIC Non-Native Invasive Species.
- Marine Non-native species records from Natural Resources Wales (NRW) monitoring research and ad-hoc sightings.

Using the marine non-native species listed in Minchin *et al.* (2013), each species was searched for on the NBN Gateway to identify which datasets had contributed distribution data on those species in terms of number of species recorded (Table 4) and number of observations on each species (Table 5). Using this approach, 38 datasets contained information on marine non-native species. The number of total observations made across all datasets varied considerably amongst species, with the ten highest observations shown in Table 6.

Table 4. Number of species recorded by dataset (where over 10 species have been recorded). Appendix C contains full list of datasets.

Organisation	Dataset	Number of species recorded
Marine Conservation Society	Seasearch	26
Joint Nature Conservation Committee (JNCC)	Marine Nature Conservation Review and associated benthic marine data held and managed by JNCC	25
Natural Resources Wales	Marine Data from Technical Support (Research & Monitoring)	14
British Phycological Society	Seaweed data for Great Britain and Ireland	14
Centre for Environmental Data and Recording	Marine Data from Northern Ireland	14
Marine Biological Association	The Archive for Marine Species and Habitats Data (DASSH) Volunteer Sightings	12
Marine Biological Association	The Archive for Marine Species and Habitats Data (DASSH) Expert Sightings	11
Natural Resources Wales	Marine Records from Pembrokeshire Marine Species Atlas	11
Scottish Natural Heritage	Marine Species Data (Benthic surveys 1993 – 2012)	11

It should be noted that access is limited for some datasets which prevents complete presentation of the picture on marine non-natives. Two datasets which appear to contain information on marine non-native species but are not accessible to the public include:

- Marine Science Project - Citizen Science Settlement Panels. Data of both native and non-native fouling species detected on settlement panels deployed in Cornwall during 2012.
- Marine Biological Association - MarClim UK & Ireland rocky shore surveys.

7.3. Datasets and Numbers of Species Observations

In addition to understanding how many species are recorded by different dataset providers, it is also valuable to see which data providers are supplying large volumes of data on marine non-native species distribution (Table 5). The JNCC Marine Nature Conservation Review began in 1987 and was completed in 1998. During the course of the review, significant amounts of information were collected on species and habitats in the UK, which contributed to this dataset. Data from this project was placed on the Marine Recorder database, also used by several conservation bodies, which is fully compatible with the NBN Gateway. This dataset provided the largest number of marine non-native species records, and contains useful baseline information. However in terms of present day contributions to the marine non-native species knowledge base, the Marine Conservation Society's Seasearch project is currently providing significant amounts of records. This project is delivered through a volunteer network of divers who are trained to carry out surveys and supported by

identification guides of species found in UK waters. The high volume of observations from this project highlights the significant role that citizen scientists could play in supporting monitoring campaigns.

Table 5. Number of observations of marine non-native species recorded by dataset (where number of recordings is over 1000) Appendix D contains full list of datasets.

Organisation	Dataset	Total number of marine non-native species observations
Joint Nature Conservation Committee (JNCC)	Marine Nature Conservation Review and associated benthic marine data held and managed by JNCC	3207
Marine Conservation Society	Seasearch	2589
British Phycological Society	Seaweed data for Great Britain and Ireland	1538
Conchological Society of Great Britain & Ireland	Mollusc (marine) data for Great Britain & Ireland	1376
Kent & Medway Biological Records Centre	Invasive non-native species in Kent records from 1900 to March 2012	1131
Marine Biological Association	2005 - ongoing United Kingdom MarLIN Shorething timed search results	1055
Natural Resources Wales	Marine Data from Technical Support (Research & Monitoring)	1026

Distribution data on several marine non-native species is particularly high when analysed using all accessible datasets. Reasons for this are unknown although date of introduction could be factor such as in the case of *Crepidula fornicata* and *Bonnemaisonia haimfera*, both of which were first identified during the late 1800s. Other species such as *Sargassum muticum* arrived in the UK more recently, but rapid spread combined with concerns about the ecological impact on native species may be a factor in the high number of observations. In addition, some marine non-natives may be easily distinguishable from other species and recorder confidence may be higher than for other more cryptogenic species.

Table 6. Top ten marine non-native species based on total number of observations (Appendix D for full details).

Species	Total number of observations across all datasets
Crepidula fornicata	4498
Austrominius modestus	3574
Sargassum muticum	1368
Bonnemaisonia hamifera	1009
Styela clava	954
Crassostrea gigas	928
Asparagopsis armata	881
Colpomenia peregrina	587
Eriocheir sinensis	318
Antithamnionella spirographidis	312

In summary, large amounts of distribution data are available through the NBN Gateway providing a valuable central tool for those interested in marine non-native species and understanding what survey activity is taking place.

RECOMMENDATIONS

- Where established species do not have information on NBN Gateway, this should be rectified.
- Datasets, unless they contain sensitive species or habitat data, should be made publicly accessible on the NBN Gateway.
- *Tiostrea lutaria* should be updated to its accepted taxonomic name *Ostrea chilensis* on the NBN Gateway.
- Dataset providers should consider, if feasible, greater use of the 'absence' option within the NBN Gateway when conducting targeted marine non-native species searches to indicate the species has not yet established or entered the area.

8. Non-native Species Data in Welsh Coastal Waters

Conducting a similar exercise to that covered in section 5 but focusing only on Wales shows that a total of 23 marine non-native species have been recorded around the Welsh coastline on the NBN Gateway (Appendix E). In addition a minimum of 18 datasets have contributed distribution data on non-natives in Welsh waters. This number is quoted as a minimum as the way the data is currently presented, limits the ability to identify which Marine Biological Association datasets provided the information. Using the NBN Gateway, mapped data is provided by organisation rather than by dataset, making localised analysis more challenging at present. Table 7 displays the number of entries by species recorded for Wales.

Table 7. Number of entries by marine non-native species found in Wales.

Species	Total number of entries for Wales	Number of datasets contributing data*
Antithamnionella spirographidis	51	5
Antithamnionella ternifolia	19	2
Asparagopsis armata	6	3
Austrominius modestus	1000s	Uncertain due to limitations with extracting data
Bonnemaisonia hamifera	40	4
Bugula neritina	4	3
Bugula stolonifera	2	1
Colpomenia peregrina	63	7
Corella eumyota	12	3
Crassostrea gigas	65	4
Crassostrea virginica	21	1
Crepidula fornicata	423	9
Diadumene lineata	4	4
Eriocheir sinensis	4	1

Ficopomatus enigmaticus	18	5
Goniadella gracilis	59	3
Mercenaria mercenaria	18	5
Perophora japonica	2	2
Petricola pholadiformis	3	3
Polysiphonia harveyi	16	2
Sargassum muticum	147	5
Solieria chordalis	12	3
Styela clava	169	9

* Minimum number of datasets based on inability to discriminate between MBA datasets.

RECOMMENDATIONS

- List contained in Appendix E should be validated against most recent Natural Resources Wales (NRW) records for marine non-native species to ensure correlation between the two sources and any gaps in data rectified i.e. *Didemnum vexillum* should be entered onto NBN Gateway as present for Holyhead Marina but absent in other marinas that have been surveyed to date.

9. Conclusions

Evidence of regular monitoring programmes for marine non-native species appears to be limited from the methods employed to search for such data, although programmes such as Marine Aliens I and II have provided valuable baseline information to assist with future monitoring programmes. Though many locations have now been mapped for the presence of marine non-native species, often this appears to be a single exercise and there is a need to ensure regular follow up activity to monitor changes to individual sites. Using the NBN Gateway to search for distribution records on marine non-native species indicates that a wide variety of organisations are collecting data on non-native species, although data in this format is currently predominantly limited to presence and absence data rather than quantitative results, but examining the raw data may show that greater detail is available in some instances. The significant input by the Marine Conservation Society's Seasearch programme and the Marine Biological Association's "Shore Thing" timed species surveys highlight the value and contribution that citizen scientists can make to the knowledge base on marine non-native species. With clear directives, the co-ordinators of such programmes could assist with targeting efforts on priority sites and habitats to support GB commitments to ensure greater coverage of our coastlines in the future. Obtaining clarity on the type of data that is required to fulfil EU obligations could help to initiate dialogue with some of these volunteer programmes about standardising data collection or devising target surveys for non-native species, in addition to formalised expert-led monitoring programmes on key sites.

Rapid assessment surveys appear to be emerging as the method of choice for marinas, harbours and aquaculture sites, whereby large quantities of data can be rapidly collected for multiple locations, although the capability to undertake regular surveying will depend on having sufficient trained taxonomic experts who can carry out such work. In addition, consideration needs to be given as to what species

information to collect. Each rapid assessment survey identified within this review opted for a different approach in terms of species to search for and it may be useful to standardise this approach where possible in the future i.e. natives and non-natives vs. non-natives only to enable comparisons between regions. With regular monitoring programmes in place, rapid assessment surveys for single species should not be necessary unless a non-native species is discovered that had not been anticipated.

It is likely that regular monitoring programmes in some localities may exist, but that information is currently not readily accessible or identifiable either through internet searches or via the NBN Gateway. Encouraging organisations to utilise the GBNNSS portal to share information on monitoring activities for marine non-native would be a useful first step in the right direction.

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11. Appendices

11.1. Appendix A: Methodology for scientific literature search for monitoring activity

An extensive query was run using the Web of Knowledge database to identify any literature relating to monitoring or surveillance work targeting marine non-native species using the search terms shown in Table 1. The terms associated with each subject were searched for using the field tag “Topic” (which searches the title, abstract and author keywords) using the Boolean operator ‘OR’ between each term to generate a set for each subject field. The four sets were joined together, each separated by the Boolean operator ‘AND’ and a query run to extract any literature containing a combination of terms from the four subject sets. Where a term could have multiple endings an asterisk (*) was employed to enable Web of Knowledge to search for all related words e.g. marina* for marina or marinas. Quotation marks (“”) were used to search for a term containing two or more words. The search returned 289 potential items of literature.

The 289 items were evaluated for relevance in a three-stage process. Titles were scanned and literature either not relevant to non-native marine species or duplicate records were eliminated. Removal predominantly occurred in relation to terrestrial non-natives or non-natives from New South Wales or New England that were picked up using the “Country” search terms. Abstracts for the remaining 82 documents were scanned for reference to non-native surveys or monitoring within the United Kingdom. Material excluded from further analysis included articles pertaining to predictive modelling and forecasting, genetics and experiments relating to impacts of non-natives. Following a more detailed examination of the residual literature, only material where any distribution or abundance data on a non-native species was noted were retained for further analysis. A total of 45 studies were evaluated in more detail.

Subject	Topic
Non-natives	("alien species" OR "alien organism*" OR "allochthonous species" OR bioinvasion OR "bio-invasion" OR "biological invasion" OR bioinvader OR bio-invader OR "bioinvasive species" OR "bioinvasive organism*" OR "bio-invasive species" OR "bio-invasive organism*" OR biopollut* OR "exotic species" OR "exotic organism*" OR "introduced species" OR "introduced organism*" OR "species introduction" OR "species introduced" OR "invasive species" OR "invasive organism*" OR "nonindigenous species" OR "nonindigenous organism*" OR "non-indigenous species" OR "non-indigenous organism*" OR "non indigenous species" OR "non indigenous organism*" OR "non-native species" OR "non-native organism*" OR "non native species" OR "non native organism*" OR "non native species" OR "non native organism*" OR invasi*)
Marine and coastal waters	(marine OR coast OR coastal OR estua* OR ocean* OR sea OR seas OR intertidal OR subtidal OR shore* OR maritime OR lagoon* OR benth* OR demersal OR bay OR embayment OR "continental shelf" OR sand* OR rock* OR marina* OR port* OR aquaculture* OR harbour* OR artificial*)
Monitoring/ Survey	("rapid assessment survey" OR RAS OR "rapid assessment" OR survey* OR monitor* OR baseline* OR abundance OR distribution OR SACFOR OR surveillance)
Country	("United Kingdom" OR "Great Britain" OR Britain OR British OR "British Isles" OR England OR Wales OR Scotland OR Ireland OR UK or GB)

Data extracted from each piece of literature included:

- Aims of the study
- Location – geographical and type of study site i.e. marina, rocky shore
- Date and time of year
- Method
- Type: species-specific, non-natives or other
- Funding source where mentioned
- Data available on NBN Gateway

11.2. Appendix B: List of references for 44 publications identified through Web of Knowledge literature search.

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11.3. Appendix C: NBN Gateway – Species by Dataset

(Separate Excel file)

11.4. Appendix D: NBN Gateway – Species observations by dataset

(Separate Excel file)

11.5. Appendix E: NBN Gateway – Species recorded in Wales by dataset

(Separate Excel file)

Data Archive Appendix

Data outputs associated with this project are archived in folder 12/8463 on server–based storage at Natural Resources Wales.

The data archive contains:

[A] The final report in Microsoft Word and Adobe PDF formats.

[B] Excel files: Annex C to E of the report.

Metadata for this project is publicly accessible through Natural Resources Wales' Library Catalogue http://194.83.155.90/olibcgi by searching 'Dataset Titles'. The metadata is held as record no [NRW to insert this number]

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