Mapping Invasive Alien Species in intertidal habitats within Natura 2000 sites in the Solent

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Mapping Invasive Alien Species in intertidal habitats within Natura 2000 sites in the Solent

Jessica G. Taylor, Christine A. Wood and John D. D. Bishop

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Further information

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ENG_2578 - Mapping Invasive Alien Species in intertidal habitats within Natura 2000 sites in the Solent

Final Report

Jessica G. Taylor, Christine A. Wood and John D.D. Bishop

Executive Summary

Biological invasions by Invasive Alien Species (IAS) are generally accepted to be one of the greatest threats to biodiversity world-wide. The direct cost to Great Britain's marine industries has been estimated at approximately £40 million/yr (Williams *et al.*, 2010). The Solent, much of which is designated as a Special Area of Conservation (SAC) and Special Protection Area (SPA), is noted as a key entry point for IAS into the UK due to its high volumes of international shipping and recreational boating, both major vectors of IAS. These IAS pose a threat to the Solent's native biodiversity and fishery industries, especially shellfisheries, due to their potential to threaten native species, habitats or whole ecosystems. The Solent had one of the largest self-sustaining stocks of native oyster (*Ostrea edulis*) in Europe and the increasing dominance of the invasive slipper limpet (*Crepidula fornicata*) is one of the reasons for its displacement. The invasive carpet sea squirt (*Didemnum vexillum*) is also present, and has the potential to spread outside marinas/harbours having a smothering effect, covering habitats in thick sheet-like growths and interfering with fishery and aquaculture operations.

Although there has been monitoring of IAS within harbours and marinas, recognised as hot spots for IAS, the adjoining areas of intertidal habitat, often where the fisheries are operating, have been largely ignored. However, there is a strong suspicion that IAS are much more prevalent on natural shores than has been documented. We thus have a very poor understanding of whether and how IAS spread beyond their typical entry points to the region, which limits our ability to take proactive management action based on site-specific risk assessments of their subsequent impacts on the wider environment and fisheries. This lack of knowledge means it is difficult to communicate the scale of risk from IAS, limiting the marine sector's ability to take proactive management action such as promoting biosecurity plans and implementing good practice to prevent IAS impacting fisheries and the marine ecosystem.

This project aimed to respond to this identified data and information gap by developing a replicable survey methodology to map IAS within Natura 2000 sites in the Solent.

Rapid assessment surveys of 14 'Clusters' of three sites, one marina/harbour site, one nearby shore and one more distant shore, were completed in the Solent, recording alien species (AS) and native species (NS) from target lists. Twelve clusters proved suitable for full comparison of the site types. Analysing the AS readily detected on marina pontoons (the majority), Marina sites held on average 4.4 more AS than the Near shore in the same Cluster, but Near shores had on average 3.5 more AS than the equivalent Far shore. Accordingly, the recorded ratio of AS to NS was significantly higher overall in Near shores than in the matching Far shores. The average per-species occupancy of sites by AS (i.e. the frequency of a species' occurrence) declined in the same order, Marina to Near shore to Far shore, but no such trend was apparent amongst the NS surveyed, indicating an AS-specific pattern of decline in incidence with distance from a marina. Thirty-six different AS were recorded, 30 in marinas and 35 on shores. Approximately 13 AS for which there are presently no shore records for the Solent in the NBN Atlas were detected on the shore. Amongst these were the bryozoan *Watersipora subatra*, which has already achieved considerable densities on shores further west in England, and the colonial ascidian *Didemnum vexillum*, considered nationally to be a substantial threat to economic interests and native biodiversity. The bryozoan *Tricellaria inopinata* and the colonial ascidian *Botrylloides diegensis* were found to be widespread and frequent on Solent shores. Man-made substrates on otherwise natural shores appeared to promote the presence of both AS and some NS. Some well-established AS, such as the brown seaweed *Sargassum muticum* and the Pacific oyster *Magallana gigas,* caused concern at particular sites, while the colonial ascidian *Didemnum vexillum* and bivalve mollusc *Arcuatula senhousia* have the potential to reach nuisance levels in the near future.

Artificial objects and fixed structures appeared to increase the roster of AS on otherwise natural shores. Limiting the amount of artificial material on shores should be considered as a management option.

The marine sector's confidence to take proactive management action with regard to biosecurity is being enhanced by provision of site-specific lists of AS from the surveys and species identification guides. Knowledge of the actual species that they are likely to encounter and the likely threats is helping operators to appreciate the importance of biosecurity planning and to tailor their plans to their own area.

This new data has also been compared with previous surveys of IAS in Solent marinas to provide a time-frame for assessment of the risk of colonisation of natural shores by IAS from nearby marinas. Previous data on the prevalence of AS in marinas around the entire English and Welsh coasts suggests that the influence of marinas on natural shores reported here is not unique to the Solent: shores elsewhere could be similarly affected, and many of these would be in Natura 2000 sites.

This exploration of the association between IAS in marinas / harbours and intertidal areas will inform policy regarding governmental obligations under Descriptor 2 of the UK Marine Strategy (implementing the Marine Strategy Framework Directive (MSFD)). The insight gained will be applicable to the broader conservation of Natura 2000 sites, and to understanding threats to fisheries, including nursery areas, and to aquaculture.

This work will also complement our capacity to monitor the effects of the International Ballast Water Convention, by providing a baseline of IAS within the Solent Maritime SAC. As a globally important shipping destination, the Solent is likely to be among the first places in theUK to see the effects of this new regulation.

Please note, the term Invasive Alien Species (IAS) rather than Invasive Non-Native Species (INNS) has been used throughout this report as the project was funded by an EU funding stream.

This report was first published on 14 April 2022, this version was updated to include Appendix XIII and republished on 28 April 2022.

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1. INTRODUCTION

Alien (non-native, or non-indigenous) species, abbreviated here to AS, are those which have been spread, either intentionally or accidentally, beyond their natural geographical range as a consequence of human activity. In contrast, species living within their natural range are referred to as native species (NS). The additional term 'invasive' is used to specify alien species that are known to adversely affect native biodiversity or harm human wellbeing in terms of economic activity or health, thus 'invasive alien species' (IAS).

Biological invasions by IAS are generally accepted to be one of the greatest threats to biodiversity world-wide. The direct cost to Great Britain's marine industries has been estimated at approximately £40 million/yr (Williams *et al.*, 2010). The Solent, much of which is designated as a Special Area of Conservation (SAC) and Special Protection Area (SPA), is noted as a key entry point for IAS into the UK due to its high volumes of international shipping and recreational boating, both major vectors of IAS. These IAS pose a threat to the Solent's native biodiversity and fishery industries especially shellfisheries due to their potential to threaten native species, habitats or whole ecosystems. The Solent had one of the largest self-sustaining stocks of native oyster (*Ostrea edulis*) in Europe and the increasing dominance of the non-native slipper limpet (*Crepidula fornicata*) is one of the reasons for its displacement. The non-native carpet sea squirt (*Didemnum vexillum*) is also present, and has the potential to spread outside marinas/harbours having a smothering effect, covering habitats in thick sheet-like growths and interfering with fishery and aquaculture operations.

Although there has been monitoring of IAS within harbours and marinas, the adjoining areas of intertidal habitat, often of conservation status or where the fisheries are operating, have been largely ignored. As noted by Ulman *et al*. (2019) "While there are many NIS [=IAS] recorded in marinas, it is not yet understood how these hot-spots affect the natural biodiversity on a broader scale (i.e., outside the marinas)." However, there is a strong suspicion that IAS are much more prevalent on natural shores than has been documented. We thus have a very poor understanding of whether and how IAS spread beyond their typical entry points to the region, which limits our ability to take proactive management action based on site-specific risk assessments of their subsequent impacts on the wider environment and fisheries. This lack of knowledge means it is difficult to communicate the scale of risk from IAS, limiting the marine sector's ability to take proactive management action such as promoting biosecurity plans and implementing good practice to prevent IAS impacting fisheries and the marine ecosystem.

This project aimed to respond to this identified data and information gap by developing a replicable survey methodology to map IAS within Natura 2000 sites in the Solent. Comparison of this information with inventories of IAS in Solent marinas enables assessment of the risk of colonisation of natural shores by IAS from nearby marinas. This approach and the insight gained will be applicable to the conservation of other Natura 2000 sites, and to understanding threats to fisheries, including nursery areas, and to aquaculture.

The project will also improve knowledge and management of marine IAS within the Solent Natura 2000 sites, by improving future technical skills and helping limit the impacts of IAS on the condition of the Solent's Natura 2000 sites and therefore on the sustainability of marine industries.

This exploration of the association between IAS in marinas / harbours and intertidal areas will inform policy regarding governmental obligations under Descriptor 2 of the UK Marine Strategy (implementing the Marine Strategy Framework Directive (MSFD))). The timing of this work will also complement our capacity to monitor the effects of the International Ballast Water Convention, by providing a baseline of IAS within the Solent Maritime SAC. This Convention will see a tightening of the current ballast water management measures required by visiting vessels. As a globally important shipping destination, the Solent is likely to be among the first places in the UK to see the effects of this new regulation. Consequently, by gathering this data, we are ensuring that we are well positioned to provide contributions to this discussion.

1.1. Project aims

This project had the following aims:

- Develop a new rapid protocol for surveys of IAS within intertidal areas such as those of the Solent Maritime SAC. The methodology will be replicable for future Solent surveys and used elsewhere in England;
- Survey IAS at a series of locations each comprising a marina/harbour and two adjacent natural shores;
- Analyse resulting data and information from previous Marine Biological Association (MBA) surveys to elucidate the risk of spread of IAS from marina / harbour populations onto adjacent natural shores and impact on associated fisheries operations, considering both individual species and the overall risk;
- Provide better and more robust data that will increase understanding of IAS, their impacts and the feasibility of undertaking control and different management options;
- Provide data to help communicate the scale of risks to different maritime sectors (e.g. aquaculture) who are responsible for managing the different IAS pathways;
- Develop and inform suitable and feasible management actions and best practice to minimise the spread of IAS within the region. The final report will inform, promote and help relevant harbour authorities to improve biosecurity plans;
- Encourage collaboration between public bodies (Natural England, IFCAs, Cefas and MMO), local harbour authorities, IAS specialists from the MBA, and local fishermen and foster liaison on best practice to minimise the spread of IAS within the region;
- Use baseline data to inform future policy work;
- Develop a target list of IAS for future monitoring within the Solent;
- Train Natural England staff on intertidal and marina rapid survey protocols and IAS identification, improving the identification and surveying skills of up to 30+ people;
- Raise awareness amongst marina/harbour staff of IAS as an environmental threat and provide information on the IAS present at their site to assist biosecurity planning; and
- Make IAS distribution data publicly available via NBN Atlas

1.2. Purpose of this report

This report is the final report detailing the results of surveys of 14 marinas and 28 shore sites within the Solent conducted by Natural England and Marine Biological Association of United Kingdom (MBA) over two years as part of European Maritime Fisheries Fund (EMFF) grant ENG_2578. The Year 2 final report outlines the methods used, provides full analysis of the results, and assessment of impacts, future applicability of the method and details of how each aim has been achieved.

2. METHODS

The surveys were designed to elucidate as fully as possible the extent of spread of alien marine species on to Natura 2000 sites over a broad area of the Solent region. Details on how sites were selected, the target species chosen and the survey methodologies used are given below. The surveys were conducted in May - July over two years, 2018 and 2019.Site selection

Fourteen sets of sites (= ‘Clusters’) were selected to ensure a widespread across the Solent, each cluster comprising a marina or harbour (‘Marina’) and a pair of accessible shore sites, one shore relatively close to the marina (‘Near shore’) and one further away (‘Far shore’). The marinas were intended to be generally close to full salinity with permanently floating pontoons. The shores chosen were all in Special Areas of Conservation or Special Protection Areas (i.e. Natura 2000 sites), avoiding brackish conditions as far as possible. The sites surveyed are shown in Figure 1 and listed with geographical details at Appendix I.

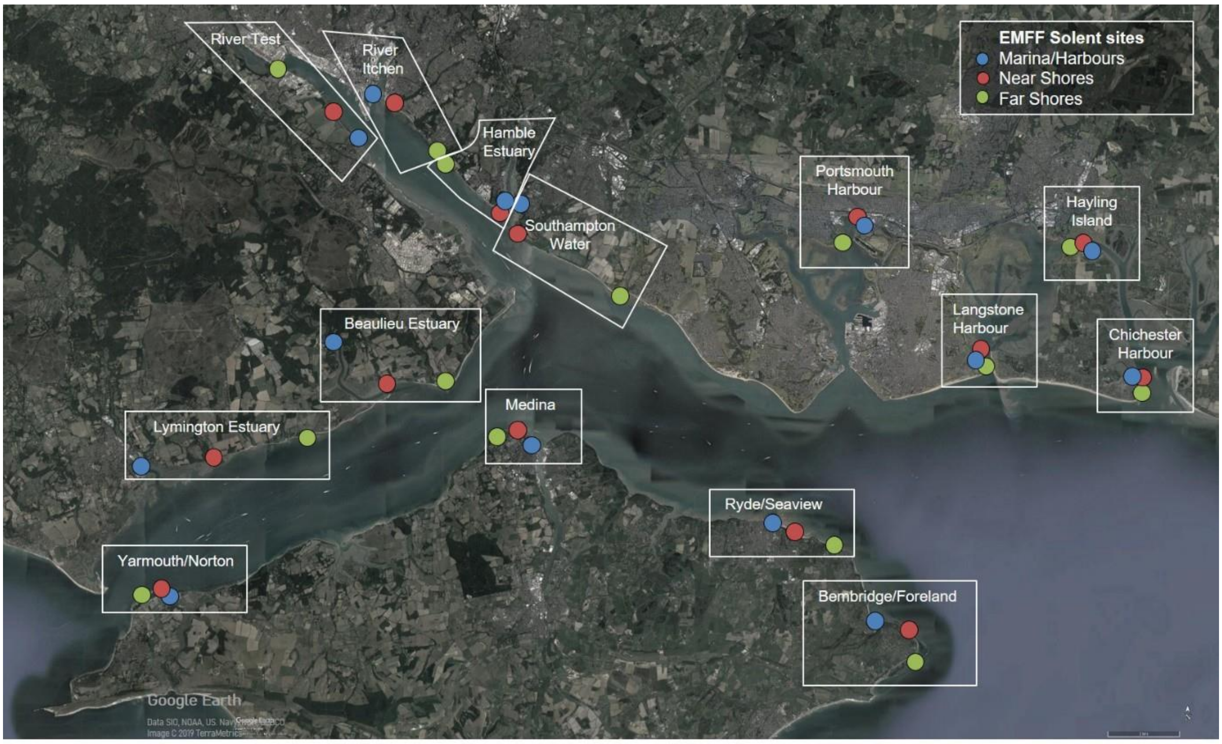


Figure 1: Map of Solent area, showing the 14 clusters of sites surveyed including marinas/harbours, near shores or far shores. Map imagery: Google Earth, © 2019 TerraMetrics.

2.2. Target species selection

A target list of 50 AS was drawn up comprising a mixture of species previously identified in the Solent, with an emphasis on those recorded in marinas/harbours, and therefore with the potential to have spread to adjoining shores, and species identified as likely arrivals from horizon scanning. Weight was also given to relevant species on the MSFD UK Priority Monitoring and Surveillance Lists (see Appendices II and XI), to ensure data gathered will help towards the application of Descriptor 2 of the UK Marine Strategy. A comparative target list of 57 NS was created comprising characterising species of Solent shores, species likely to inhabit the same ecological niche as an equivalent alien species (e.g. an equivalent solitary ascidian) and any species listed on the UK Biodiversity Action Plan (BAP). The taxonomy used follows the World Register of Marine Species (WoRMS). The AS and NS target lists are given at Appendices II and III respectively with some more detailed descriptions of the AS at Appendix IV. These target lists were drawn up to ease recording in the field, however, the survey team did not limit their observations to the target list; all AS observed and additional important NS were also recorded.

A further 5 AS were added in Year 2, either as a result of them being recorded in Year 1, e.g. *Mercenaria mercenaria*, or as a result of new information on arrival into the UK e.g. the Asian date mussel *Arcuatula senhousia*; these are also included in Appendix II.

2.3. Marina surveys

The surveys were carried out following a Rapid Assessment Survey protocol; this methodology has been used in marinas in N America and throughout the UK over a number of years (Cohen *et al*., 2005; Pederson *et al*., 2005; Arenas *et al*., 2006; Bishop *et al*., 2015). Surveys were undertaken at any state of tide and from the surface (i.e. from floating pontoons, without diving or snorkelling). Each marina was contacted in advance for permission to undertake the survey and to enable preparation of any required documentation or safety requirements. At each site, the available pontoons were apportioned equally between the three surveyors, who worked independently for one hour. In addition to inspection of the pontoons themselves, submerged artificial substrates such as hanging ropes, keep cages, fenders, etc., and natural substrates such as kelps were pulled up and examined. Hooks and scrapers were used if necessary to access material for inspection. Specimens and/or photographs were taken when appropriate. The 15-minute interval (1-15, 16-30, 31-45, 45-60 min) in which each target species was first encountered was recorded by each surveyor, and an estimate of abundance made on a three-point scale ([Not recorded], Rare-occasional, Frequent-common, Abundant-superabundant). Salinity and temperature were recorded using a YSI 30 meter, and turbidity was measured using a Secchi disk. A sample Marina Survey Recording Form is shown at Appendix V.

2.4. Shore surveys

The shore surveys were carried out following a new Rapid Assessment Survey protocol developed as part of this grant and adapted for use on shores from the methodology that has been used for some time in marinas. Prior to commencing surveys, a record was made of the prevailing environmental conditions (sea state, wind direction etc.), see Shore Environmental Recording Form at Appendix VI, and a modified Marine Nature Conservation Review (MNCR) form was completed to provide an overview of the shore.

Surveys were planned to take place during Spring tides, with low water predicted to be below 1 m. Surveys were undertaken over low tide, with survey effort commencing 30 minutes before low tide and finishing 30 minutes after low tide. Survey effort was focussed on the low intertidal and shallow sublittoral, as this is the area most likely to be occupied by AS. Each landowner was contacted in advance for permission to undertake the survey and to enable preparation of any required documentation or safety requirements. At each site, the available shore was divided into three sections, based on available area, between the three surveyors, who worked independently for one hour. All available habitat was searched, including underside of rocks and boulders, any artificial substrate (e.g. groynes) and natural substrates such as fucoids and kelps. Specimens and/or photographs were taken when appropriate. The 15-minute interval (1-15, 16-30, 31-45, 45-60 min) in which each target species was first encountered was recorded by each surveyor, and an estimate of abundance made on a three-point scale ([Not recorded], Rare-occasional, Frequent-common, Abundant-superabundant). In addition, the type of substrate that each species was recorded on was also noted. If any non-target NS species were recorded in high numbers or represented a significant record for the area but were not on the original target list, these were also noted as present to ensure the occurrence was documented. Following completion of the initial 1 h search, an additional sweep of the mid to high shore was conducted to check for any species that may have been missed. A sample Shore Survey Recording Form can be found at Appendix VII. The actual shore areas covered by each surveyor were marked onto an OS map.

2.5. Both marina and shore surveys

At the end of the hour the surveyors gathered to compare notes and record joint summary observations of both AS and NS on Summary Marina Survey Forms and Summary Shore Survey Forms, which are provided at Appendices VIII and IX. Specimens were collected to substantiate significant findings, or for further discussion, and relaxed prior to preservation if required for laboratory identification or as reference material for significant records.

On completion of the survey, all equipment was washed with a disinfectant and then rinsed in fresh water to prevent transfer of IAS between sites. All recording forms were photographed as a back-up.

Following the completion of each year's surveys the preserved samples and photographs were examined to confirm species identifications and the relevant recording forms annotated accordingly. Taxonomic experts were consulted when required. Some seaweed samples were sent to Nature Metrics Ltd for DNA identification. All data from the survey forms was collated in Microsoft Excel. Relevant data regarding locations, species and abundances was added to Natural England's Marine Recorder database, the benthic survey data management system used widely within the UK's statutory nature conservation bodies to store and query benthic sample data across the UK's offshore and inshore waters. This data automatically will be uploaded to the NBN Atlas (the National Biodiversity Network, see NBNatlas.org), making it publicly available. The metadata for the surveys has been provided to MEDIN, the Marine Environmental Data and Information Network, which promotes sharing of, and improved access to, biodiversity data. It is an open partnership and its partners represent government departments, research institutions and private companies.

An assessment of the adequacy of the one-hour search interval was made by checking whether the rate of discovery of new taxa had fallen to a very low level by the fourth 15-minute interval.

While visiting the marinas and shores, outreach conversations were initiated with marina operators and interested yacht owners or beach users with the aim of raising awareness of IAS. Waterproof copies of the MBA-produced Identification Guide for Selected Marine Non-Native Species, were handed out to interested parties.

2.6. Field team details

The core field team remained the same for all three deployments in Year 1 and the first two deployments of Year 2: Jessica Taylor from Natural England and John Bishop and Christine Wood from the MBA. During the final (third) deployment in 2019, Jessica Taylor was incapacitated and was replaced for active fieldwork by Ruth Crundwell (Natural England). In addition, over 30 Natural England staff (maximum of 3 staff per site) accompanied the core survey team on surveys to observe the methodology and improve their IAS identification skills (Figure 2).

Figure 2: JT and CW about to start the first survey site, FVR SHR, with three other members of Natural England staff. Image: J. Bishop.

2.7. Health and Safety

A generic risk assessment was carried out prior to the survey work. A dynamic risk assessment was then carried out on site prior to commencing survey work to confirm suitabilityof exit points from the shore and identify any site-specific risks.

Primary health and safety concerns related to operating across large areas of either rocky habitat, on which it is easy to slip and fall, or fine sediment, in which it is easy for people to get stuck. This was mitigated as far as possible by planning routes across the site prior to commencing surveys and carrying a throw rope. Other key risks included becoming trapped by incoming tides and exposure risks, typically associated with either of the two aforementioned concerns.

All staff wore appropriate Personal Protective Equipment (PPE) for survey work, including life jackets in marinas, and carried a mobile phone. Mobile phone signal in each area had been checked using Vodafone coverage checker. All staff were provided with the tidal information for the survey areas and notified of appropriate entry and exit points to the shore and the meeting place after survey work was completed.

2.8. Survey permissions

Access permissions from relevant landowners and harbour masters were obtained by Natural England prior to commencing surveys. Data collected at each site has been provided to the relevant landowner / harbour master to increase awareness of biological communities present at their site, an example is included at Appendix XII.

2.9. Data analysis

T-tests and correlations were made using Minitab 18. Resemblance matrices, the MDS plot and ANOSIM analyses were generated in Primer 6.

For analyses comparing the presence of AS in 'Marinas' and on 'Near' and Far' shores, the species lists of both AS and NS were restricted to those taxa for which the marinas offered suitable habitat that was accessible for surveying at all states of the tide. In effect, this meant those species that readily colonise floating pontoons. This ruled out infaunal species such as *Ruditapes philippinarum* and *Mercenaria mercenaria*, and algae characteristically found on soft shores, for instance. Appendices II and III indicate which species were not included in the analyses. Only records of live organisms were included.

3. RESULTS

All surveys were completed successfully.

The detailed AS and native occurrence data for each site is provided in Appendix XIII. The environmental measurements of salinity, temperature and turbidity collected at each marina and environmental conditions noted for each shore site are reported in Appendix X. MNCR forms for each shore site were completed. All species records have been entered into Marine Recorder and will automatically be uploaded to the NBN Atlas. The survey metadata has been entered into MEDIN. Site-specific species lists, anexample of which is shown at Appendix XII, have been sent to all landowners.

3.1. Basic survey data

Overall, 1770 species-occurrence records were noted (including both AS and NS), relating to 156 different species.

In total 36 different AS were recorded during the surveys, 30 from marinas and 35 from shores: 1 cnidarian, 5 arthropods, 5 molluscs, 3 annelids, 6 bryozoans, 8 ascidians, 3 brown algae, 3 red algae and 2 green algae. The seven species restricted to one or other habitat were four single occurrences, plus two infaunal bivalves (included in the overall AS target list, but not detectable in marinas), and two algal taxa recorded only on the shore: *Codium fragile* (three occurrences) and Solieriaceae sp. (nine occurrences).

The most frequent AS on shores were: *Austrominius modestus* recorded on 27 out of 28 shores; *Styela clava*, *Crepidula fornicata* and *Sargassum muticum* (all present on 21 shores); *Tricellaria inopinata* and *Ammothea hilgendorfi* (both recorded on 20 shores), see Figure 3.

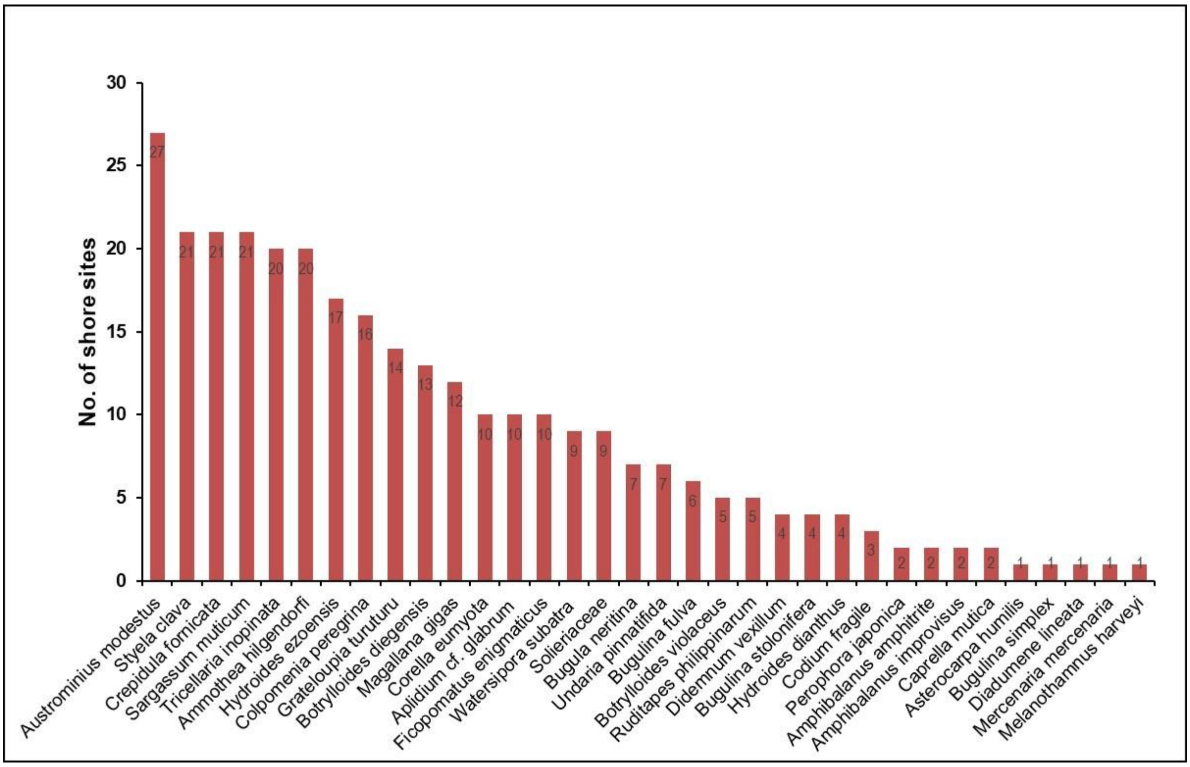


Figure 3: Ranked bar chart of number of shore sites occupied by each AS (Near and Far shores included).

The most frequent AS in marinas were: *Austrominius modestus* (found in 12 out of 14 marinas); *Hydroides ezoensis* and *Sargassum muticum* (both recorded in 11 marinas); plus *Styela clava*, *Aplidium* cf. *glabrum, Bugula neritina*, *Tricellaria inopinata*, and *Grateloupia turuturu* (all noted in 10 marinas), see Figure 4.

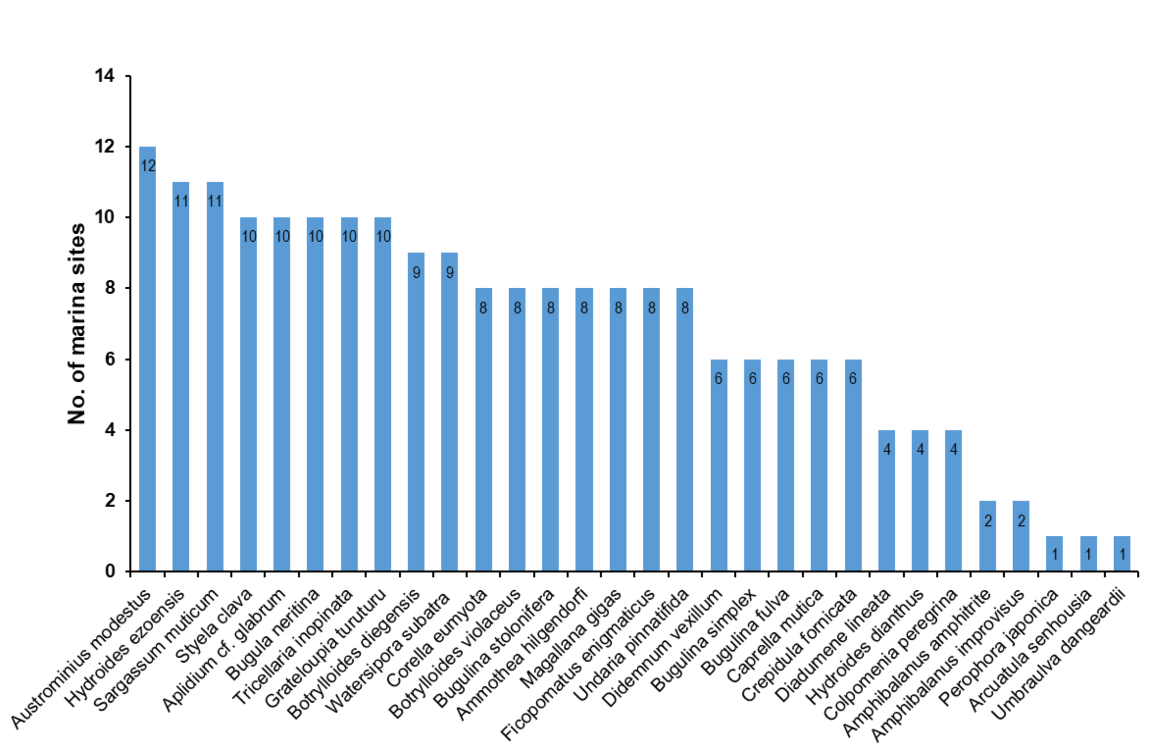


Figure 4: Ranked bar chart of number of marina sites occupied by each AS.

Of the 50 AS on the original target list, 20 were not found during the current surveys. However, a further five AS, not on the original target list, were recorded: *Bugulina fulva*, *Mercenaria mercenaria*, *Umbraulva dangeardii*, a Solieriaceae species and *Arcuatula senhousia* (only as recently dead shells).

Of the 57 NS listed for active recording, 54 were found at least one site. A further 66 native species/taxa were also noted.

Based on data held in NBN Atlas, 13 AS have been recorded for the first time intertidally on natural shores in the Solent: *Aplidium* cf. *glabrum*; *Botrylloides violaceus*; *Botrylloides diegensis*; *Didemnum vexillum*; *Bugula neritina*; *Watersipora subatra*; *Bugulina stolonifera; Caprella mutica; Asterocarpa humilis; Perophora japonica; Amphibalanus amphitrite*; *Amphibalanus improvisus* and a Solieriaceae species (although we are aware of intertidal records for some of these that do not appear on NBN Atlas).

The additional species were not included in the formal data analyses and statistical comparisons, since they had not been recorded consistently throughout the survey period.

The maximum number of AS found at any of the 14 Marina sites was 22, and the maximum recorded at any of the 28 Near/Far shore sites was 21 (Figure 5).

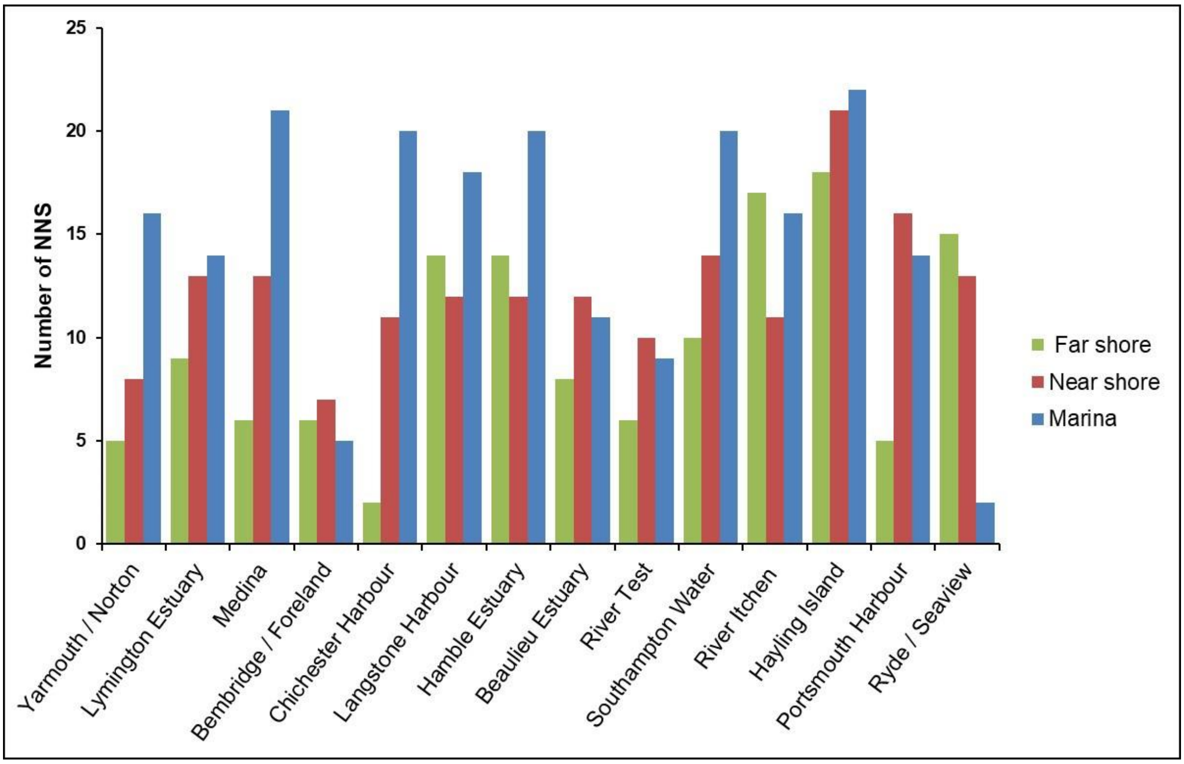


Figure 5: Bar chart of numbers of AS recorded in each Cluster, by site type (site clusters from left to right: green = Far shore, red = Near shore, blue = Marina).

Although surveys were completed at all sites, two of the 14 marinas were found to host severely reduced biodiversity caused by hydrographic features not appreciated at the planning stage. BEM HBR is an enclosed harbour into which a river discharges. The river flow is controlled by a tide-gate immediately upstream of the harbour, operating as a flood defence to prevent tidal inundation of adjacent marshland. The tide-gate generally retains river flow for periods spanning high tide and discharges the accumulated water into the harbour as sea level falls. The resultant pulsing of freshwater flow causes periodic low levels of salinity in the harbour, particularly but not exclusively in times of high rainfall. (A salinity value 34.9 psu was recorded during the survey on 14/06/2018 but 15 psu was recorded in the harbour during a visit on 08/07/2019, a dry day following a dry period with only 0.7 mm of rainfall recorded in the previous 10 d in Southampton: Southampton Weather Station at southamptonweather.co.uk).

The second site, RYD MAR, was found to partly dry out at low tide, with the pontoons grounding. In addition, a small river has recently been diverted into this harbour as part of a flood prevention scheme.

These two marina sites hosted a much-reduced diversity of target species compared to the communities of the non-emptying and near-full–salinity marinas in the other clusters. They were thus deemed unsuitable for inclusion in many aspects of the analyses because they had very little potential to influence the biotas on the shores within the same cluster. Accordingly, data from these two clusters was excluded from analyses involving the comparison of shore sites based on designation as ‘Near’ and ‘Far’ from a fully populated ‘Marina’.

3.2. Data analysis

3.2.1. Trends in numbers of AS

Based on comparison between sites within the same cluster, the number of AS recorded differed significantly between site types, with Marinas having the most species and Far shores the fewest (Table 1, Figures 5 and 6).

Table 1. Mean numbers of AS recorded per site for the three site types, and significance levels (Pairwise t-tests) for differences in numbers of AS between the site types across 12 clusters of sites.

Mean number of AS per site	
Marina	16.7
Near shore	12.3
Far shore	8.8

	Marina	Near shore
Near shore	P = 0.003	
Far shore	P < 0.001	P = 0.024

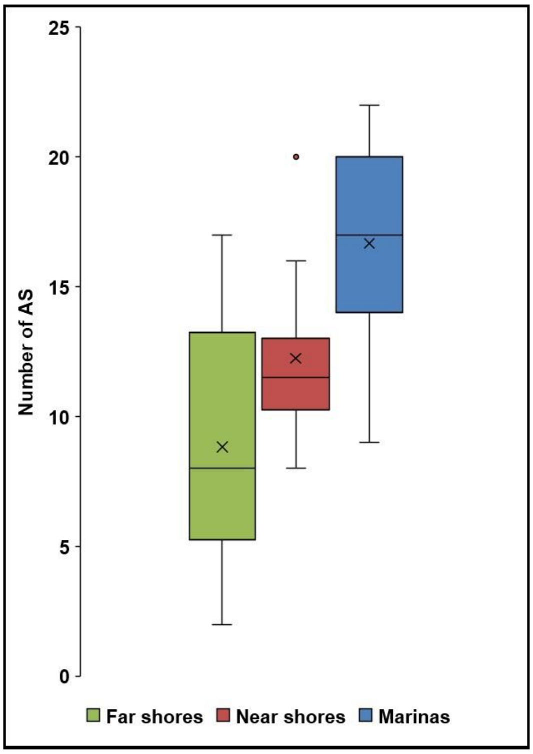


Figure 6: Box plot of numbers of AS recorded for the three site types (Far shore, Near shore and Marina) across the 12 clusters of sites. (Left to right: green = Far shores, red = Near shores, blue = Marinas).

3.2.2. AS to NS ratio on shores

The ratio of the number AS recorded to the number of NS recorded was higher in the Near shores than the Far shores across the 12 clusters (Pairwise t-test, p = 0.001; Figure 7).

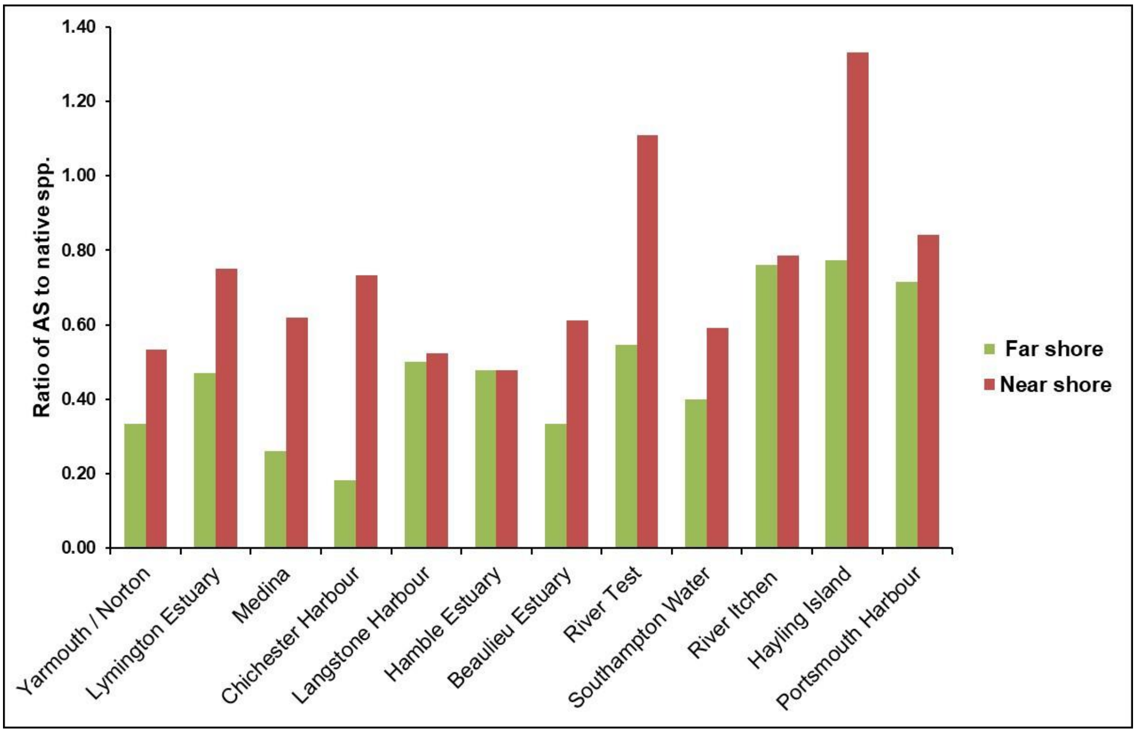


Figure 7: Bar chart of the ratio of alien species (AS) to native species (NS) from the respective target lists recorded on the Near (red) and Far (green) shores in the 12 clusters of sites.

3.2.3. Species composition of AS assemblages

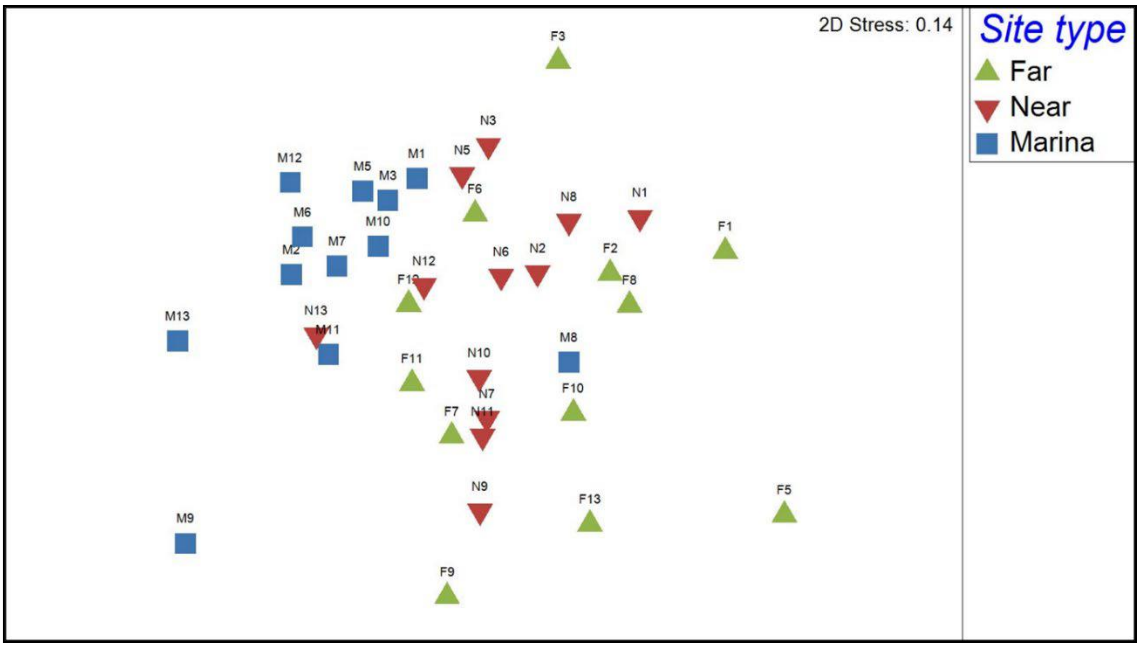


Figure 8: Multidimensional Scaling (MDS) plot of the 36 sites, derived from a Bray-Curtis similarity matrix with the site types distinguished by symbol. Site labels: M = Marina, N = Near shore, F = Far shore, with numbers indicating Cluster which are in the order shown in Figure 5, left to right.

A Bray-Curtis similarity matrix was calculated for all sites surveyed in the 12 clusters using the AS data. An MDS plot based on this matrix (Figure 8) showed the Marina sites as an almost discrete grouping, with the Near and Far shore sites alongside the marina grouping and largely intermingled with each other, with the Near shore sites slightly closer overall to the Marina sites. Two-way crossed ANOSIM analysis (without replicates) with 999 random permutations indicated that both Site type (Marina, Near shore, Far shore) and Cluster (the 12 clusters of three sites) were both associated with significant differentiation, although with intermediate values of the test statistic: Site type, Rho = 0.508, P = 0.001; Cluster, Rho = 0.35, P = 0.001). A one-way ANOSIM on Site type limited to Near shore and Far shore sites indicated that the two site types alone were not distinct (Global R = 0.026, P = 0.26)

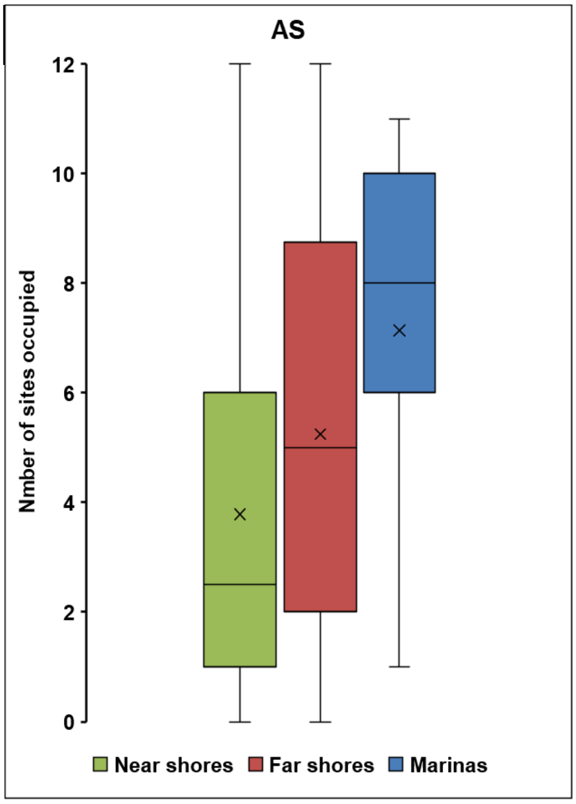
3.2.4. Site occupancy by AS and NS

The mean number of sites occupied by an AS across the 12 clusters declined progressively and with high statistical significance from Marina to Near shore to Far shore (Table 2, Figure 9A). This pattern was not present amongst NS, which showed only a marginally significant decrease in site occupancy from Marina to Near shore and a marginally significant increase from Near shore to Far shore (Figure 9B). AS that showed a clear pattern of decline in site occupancy with distance from a Marina included *Aplidium* cf. *glabrum*, *Botrylloides diegensis, Botrylloides violaceus*, *Bugulina stolonifera*, *Caprella mutica*, *Corella eumyota* and *Undaria pinnatifida*.

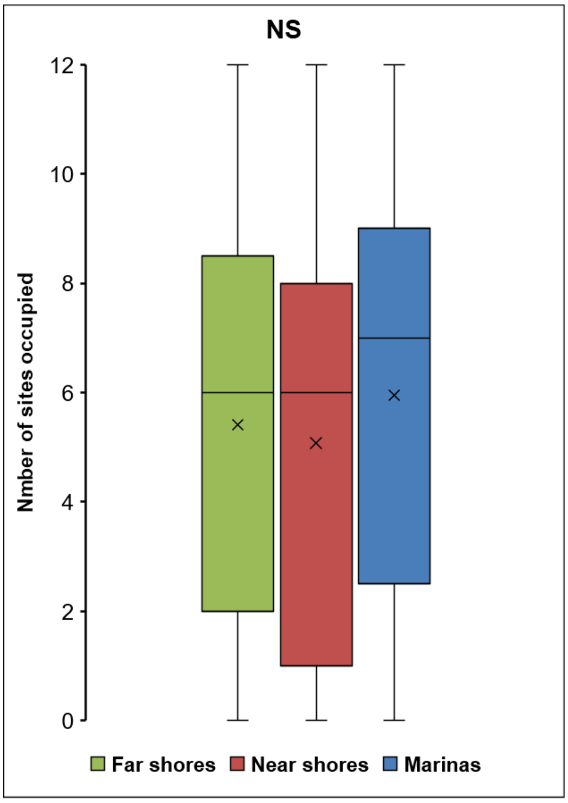
For both AS and NS, the site occupancy by the suite of individual species was positively correlated in each pairing of site types (Marina and Near shore, Marina and Far shore and Near shore and Far shore), with high statistical significance. Thus, the different species tended overall to show a similar relative level of occupancy across the site types, in the case of AS maintained alongside the general decline in occupancy from Marina to Near shore to Far shore. The scatter plots in Figure 10 illustrate the clear correlation of the respective species' frequency of occurrence between the two shore site-types for both AS and NS, combined with a significantly higher site occupancy at Near shore sites for AS but a non-significant trend for higher occupancy at Far shore sites for NS.

Table 2. Mean number of sites (out of 12) occupied per species for AS (28 species) and NS (41 species), plus significance values of t-tests paired by species comparing site occupancy between site types, and correlations between site types of occupancy by species.

	AS		NS	
	Mean number of sites occupied per species		**Mean number of sites occupied per species**	
Marina mean	7.14		5.95	
Near shore mean	5.25		5.07	
Far shore mean	3.79		5.42	
	Paired t-test	**Correlation**	**Paired t-test**	**Correlation**
Marina vs Near shore	P = 0.001	0.674; P < 0.001	P = 0.069	0.711; P < 0.001
Marina vs Far shore	P < 0.001	0.592; P = 0.001	P = 0.305	0.643; P < 0.001
Near shore vs. Far shore	P < 0.001	0. 877; P < 0.001	P = 0.075	0.951; P < 0.001



A



B

Figure 9. Box plots for AS (left = A) and NS (right = B) of mean number of sites (out of 12) occupied per species in the three site types (Green = Near shores, red = Far shores, blue = Marinas).

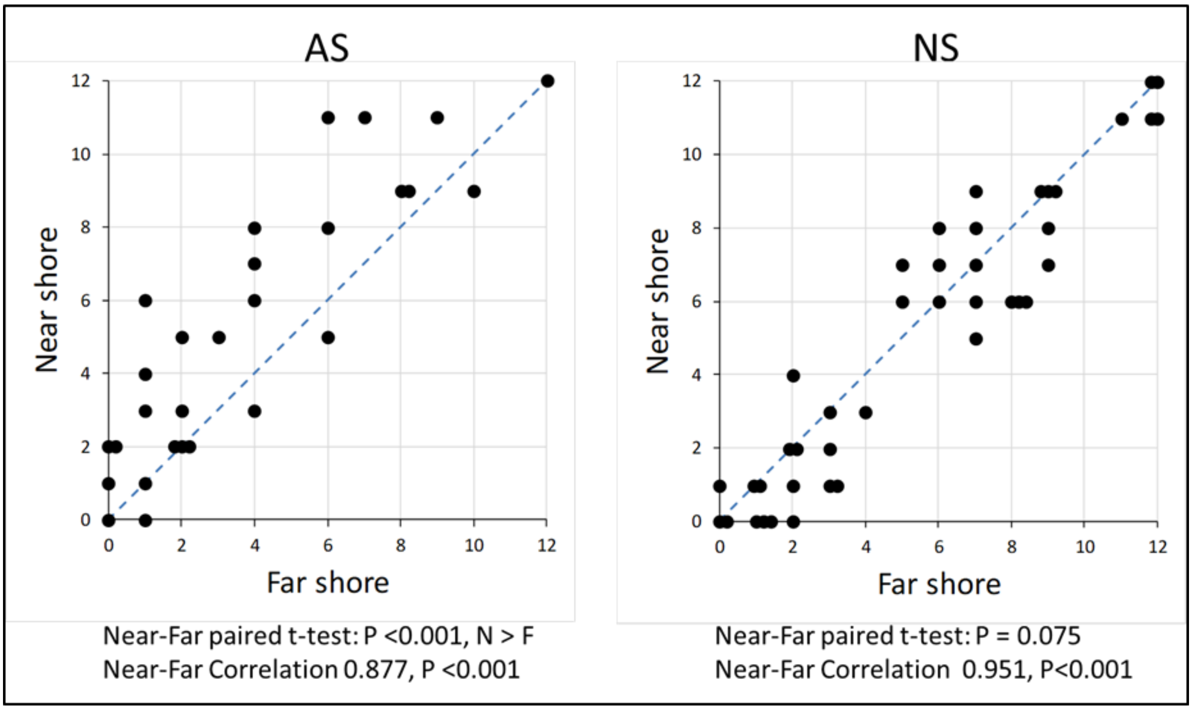


Figure 10: Bivariate plots for AS (left, 28 species) and NS (right, 41 species), with lines of equality, of number of sites occupied by each species on Near shores and Far shores. Co-incident points have been separated by 0.2 on the x-axis.

3.3. DNA Analysis

Seven specimens were provided to Nature Metrics for DNA identification. This included 4 specimens identified as Solieriaceae, possibly *Agardhiella subulata* or *Sarcodiothica gaudichaudii* from Hook Spit, Seaview, Northney and Hamble Common Beach; 1 red alga which is possibly *Melanothamnus harveyi* from Inchmery; 1 specimen of red alga which is possibly the first record in the Solent of *Gracilaria vermiculophylla* from Marchwood; and 1 green alga which is possibly *Umbraulva olivascens* from a marina site. The DNA analysis of seaweed samples proved to be inconclusive.

3.4. Species of Interest

3.4.1. *Tricellaria inopinata*

The erect (arborescent) bryozoan *Tricellaria inopinata* was first recorded in the Solent region in 1999, when surveys indicated it was restricted to approximately 75 km of the south coast from Swanage to Chichester Harbour (Dyrynda *et al*., 2000). By 2012, the species had spread along both the east and west coast of Great Britain as far north as Orkney. The great majority of these records were from marinas and harbours, and the species has not yet been widely reported on natural shores. During the present surveys it was found to be widespread and of frequent occurrence on Solent shores, with substantial additions to the existing records on NBN Atlas (Figure 11).

Figure 11: Existing NBN Atlas shore records (yellow) and new shore records (red) of the alien bryozoan *Tricellaria inopinata.* Map Imagery: Google Earth, © 2019 TerraMetrics.

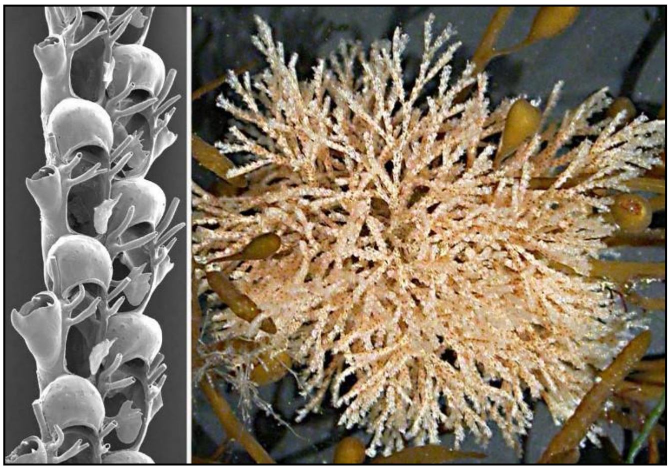


Figure 12: *Tricellaria inopinata,* left image = Scanning Electron Microscope (SEM) image of *Tricellaria inopinata*, and right image = *Tricellaria inopinata* growing on *Sargassum muticum*.

3.4.2. *Didemnum vexillum*

In 2009, the alien colonial ascidian *Didemnum vexillum* (Carpet Sea-squirt) was found in marinas in Gosport (3 sites), Lymington and Cowes (Bishop *et al*., 2015), making the Solent arguably the most extensive set of populations in the UK at that early stage. The shore records from the present surveys in the Langstone Harbour and Chichester Harbour Clusters (single shores in each case) and both shores of the Hayling Island Cluster (Figure 13) are, to our knowledge, the first documented occurrences on natural shores in the region (Figure 14). Three of these records were as Rare-occasional and the fourth, one of the Hayling Island shores, as Frequent-common; although they represent a progression in the colonisation of the Solent, no occurrence of *D. vexillum* on the shore was at a level to cause a nuisance. The record from the Marina near Yarmouth, Isle of Wight, is in a new coastal area, albeit opposite to Lymington on the mainland.

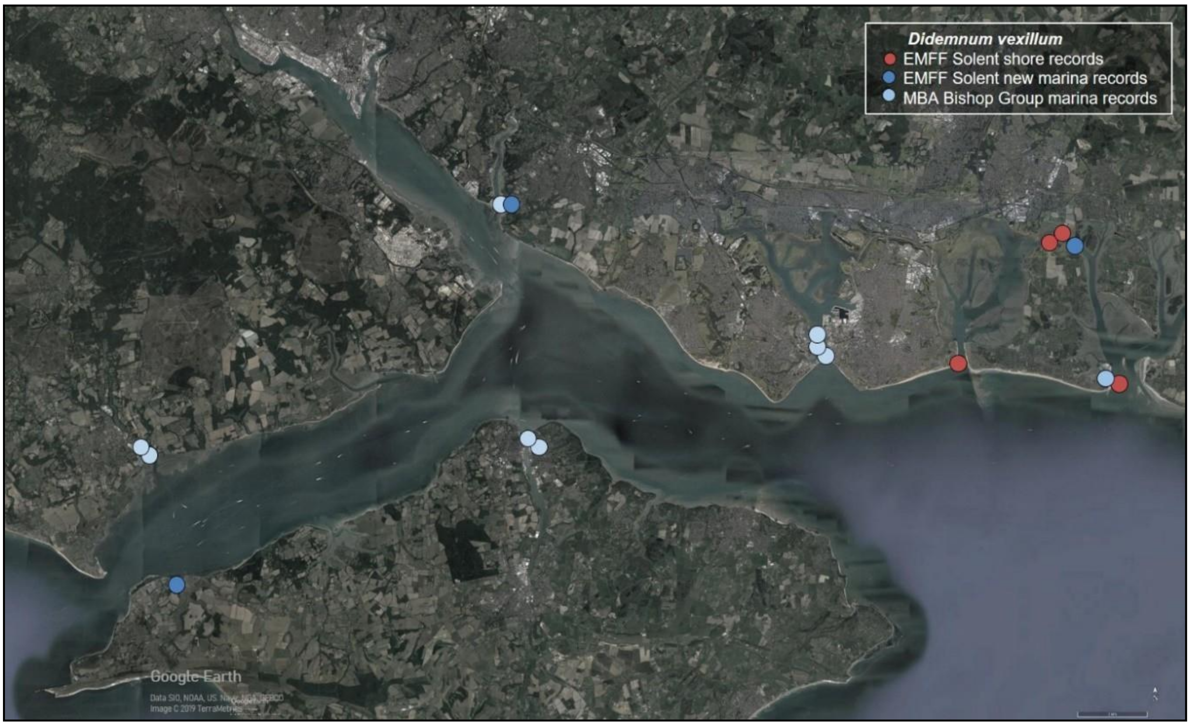


Figure 13: Marina records across the Solent of the alien ascidian *Didemnum vexillum* from previous MBA surveys (pale blue), plus new marina records (mid-blue) and new shore records (red) from the EMFF surveys. Map Imagery: Google Earth, © 2019 TerraMetrics.

Figure 14: *Didemnum vexillum* on shore at FTC SHR.

3.4.3. *Hydroides* spp.

In 1982, very large populations of the alien serpulid tube-worm *Hydroides ezoensis* were noted on artificial structures throughout Southampton Water, with much smaller scattered occurrences elsewhere in the Solent region (Stanswood Bay to Chichester Harbour, plus

Cowes and Seaview on the Isle of Wight), and re-examination of preserved material indicated the presence of the species back to 1977 (Thorp *et al.,* 1987). These were the first records of the species in the UK. A broad-scale survey of about 16 ports and harbours away from the Solent, north to Oban and Middlesbrough, did not encounter the species (Thorp *et al*., 1987). The NBN Atlas (as of December 2019) has 118 records of *H. ezoensis*, all in the Solent region except one off N. Cornwall. The NBN Atlas records in the Solent region are overwhelmingly from offshore samples or in dock or marina sites. Thorp *et al*. (1987) noted one intertidal occurrence of *H. ezoensis*, at Southsea Castle. In the present surveys, the species was recorded on 17 Solent shores out of the 28 surveyed (Figure 15) and in 10 of these occurrences the species was classed as Frequent-common or Abundant-superabundant. *H. ezoensis* is thus documented here as a numerous and widespread component of the Solent intertidal fauna. (It has recently also been found in marinas in Grimsby, Lowestoft and Plymouth (Wood *et al*., 2016, 2017; CW & JB, unpublished observations).

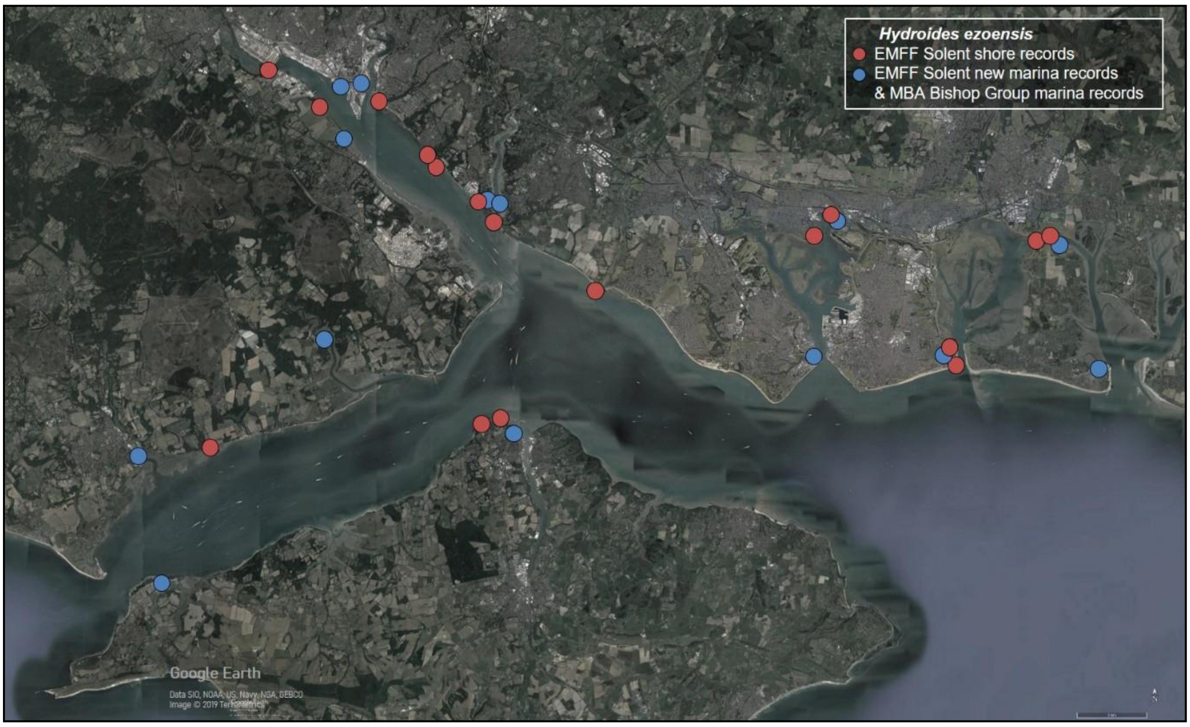


Figure 15: Recent marina records of the alien serpulid tube-worm *Hydroides ezoensis* from the EMFF surveys plus other MBA RASs (blue), and shore records from the EMFF project (red). Map Imagery: Google Earth, © 2019 TerraMetrics.

On the soft shore at Dibden Bay (R. Test Cluster), several isolated boulders had a thick fringe of serpulid tubes growing out from their near-vertical sides, with a sponge, believed to be *Hymeniacedon perlevis*, filling spaces between the worm tubes to make a solid mass (Figure 16). The serpulid component of these aggregations was dominated by *H. ezoensis*: the section shown removed in Figure 16D consisted of 46 *H. ezoensis* and seven *Spirobranchus* sp., but *Ficopomatus enigmaticus* was also present in other samples. The apparent sponge–*H. ezoensis* association, producing substantial masses, was also noted on other shores (e.g. Weston, Southampton Water Cluster). Thorp *et al*. (1987) also noted the presence of *Spirobranchus* (as *Pomatoceros*), *Ficopomatus enigmaticus* and *Hydroides dianthus* (see below) as minor components of *H. ezoensis* aggregations.

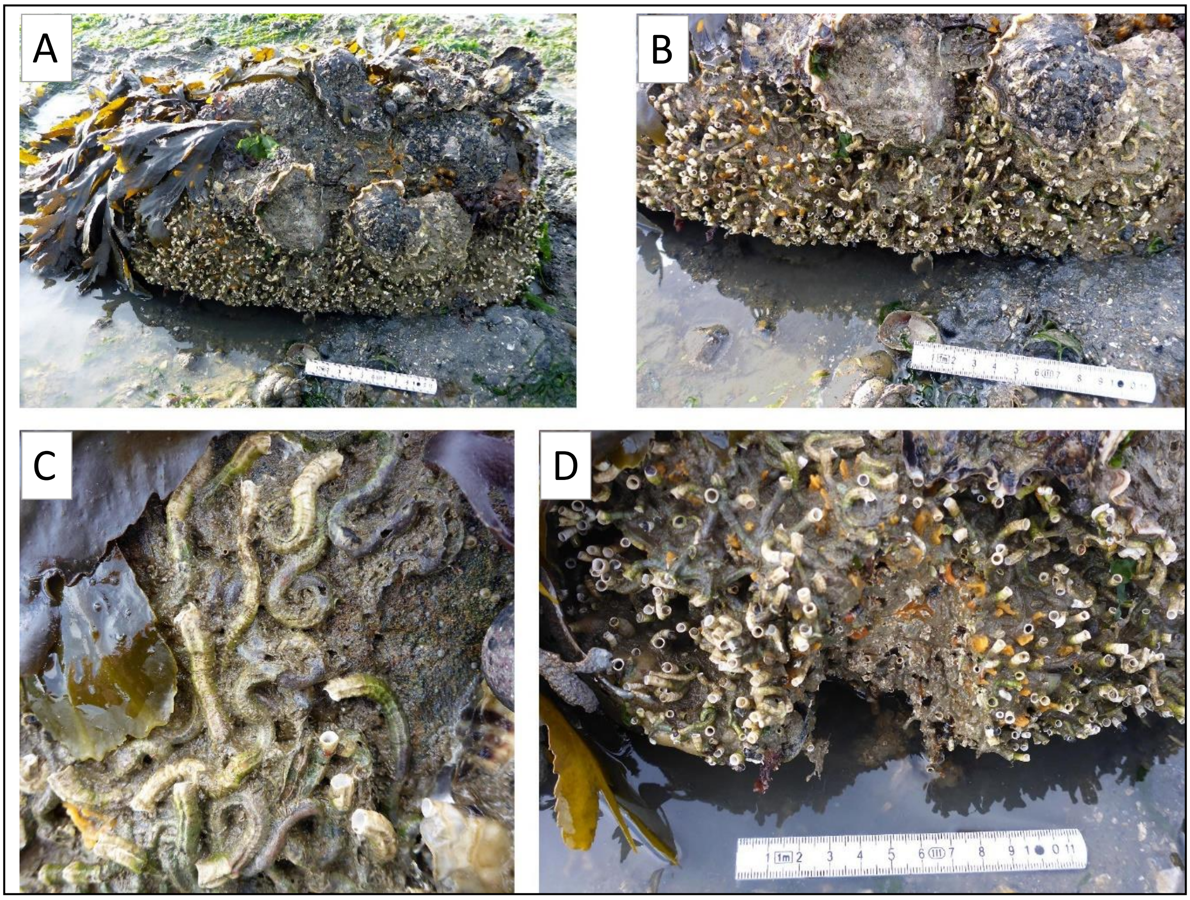


Figure 16: Serpulid mass dominated by *Hydroides ezoensis* on sides of boulder at Dibden Bay. **A**: whole boulder; note additional AS, *Magallana gigas* on upper surface, *Crepidula fornicata* in foreground. **B**: closer view of serpulid mass. **C**: close-up of *H. ezoensis* tubes growing across surface of boulder. **D**: region of serpulid mass removed for identification of worms (see text). Scale-bar 11cm.

The first UK occurrence of a second alien *Hydroides* species, *H. dianthus,* was of a single specimen on Hamble Spit in 1970 (Zibrowius, 1978), and Thorp *et al*. (1987) recorded the species in very small numbers amongst aggregations of *H. ezoensis* at Town Quay, Southampton. The NBN Atlas has a single record of this species, of a specimen in Chichester Harbour (2013). The EMFF surveys added eight sites in the Solent region, always in small numbers (recorded as Rare-occasional) and always in the company of *H. ezoensis*. The MBA team has not encountered this species elsewhere in the UK. Its long-term persistence in such apparently small numbers in the Solent seems noteworthy. Occurrences of *H. ezoensis* outstripped those of *H. dianthus* to a roughly similar extent in the three habitat types (Figure 17).

It also seems noteworthy that *Hydroides norvegica*, the common and widespread, putatively native, member of the genus, was not recorded in the EMFF surveys. Although typically subtidal, this species can also be found low on the shore. A third alien *Hydroides* species, *H. elegans*, has only been seen in the Solent by the MBA team as a single specimen in PSL MAR in the summer of 2016.

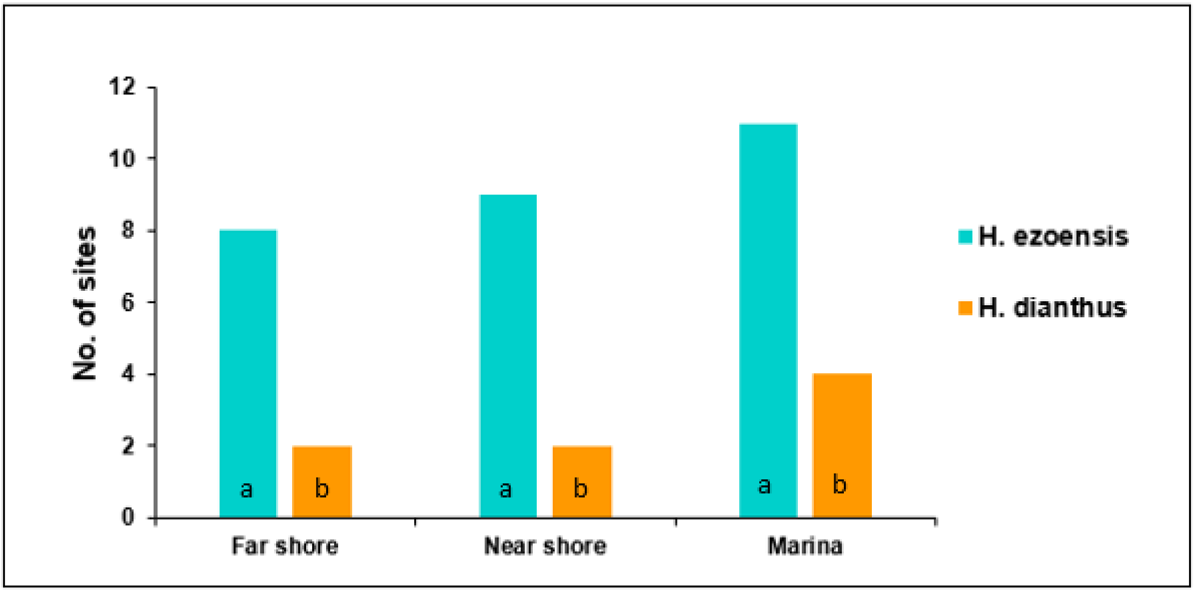


Figure 17: Occurrences of *Hydroides ezoensis* (a, blue) and *H. dianthus* (b, orange) in the three site types, Far shore, Near shore and Marina, indicating higher incidences of *H. ezoensis* when compared with *H. dianthus* across all three site types.

3.4.4. *Botrylloides* spp.

The alien colonial ascidians *Botrylloides violaceus* and *B. diegensis* are frequently difficult to differentiate. *B. diegensis* colonies can have a distinctive two-colour pattern that is sufficient to identify them but can also occur as single-colour colonies. In the latter case, they appear very similar to *B. violaceus*, and the two species can then only be reliably separated by characteristics of their brooded larvae, but these are not always present. This means that, based only on morphology, many specimens go un-identified; thus estimating relative abundances can be difficult and at some sites, *Botrylloides* may be observed but not referred to a particular species. Nevertheless, the EMFF data gives a definite suggestion that *B. diegensis* is more prevalent on shores than *B. violaceus*, despite their similar frequencies of occurrence in marinas (Figure 18). *B. diegensis* is now of widespread occurrence on shores in the Solent (Figure 19), and was recorded as abundant in all three sites in the Hayling Island Cluster.

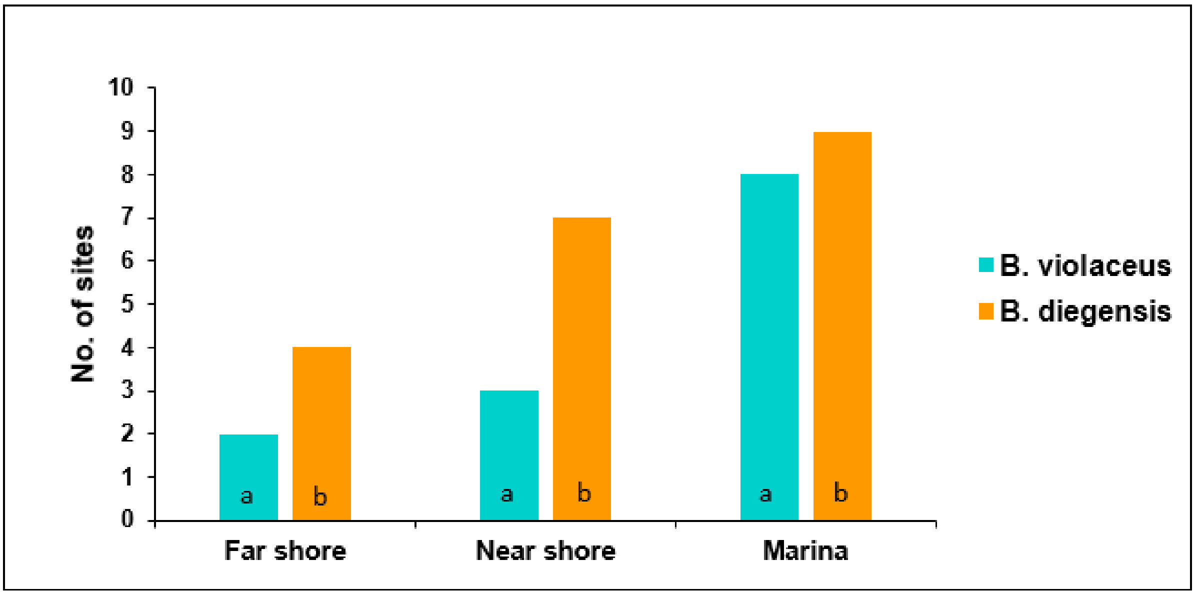


Figure 18: Occurrences of *Botrylloides violaceus* (a, blue) and *B. diegensis* (b, orange) in the three site types, Far shore, Near shore and Marina.

Figure 19: Marina records of the alien ascidian *Botrylloides diegensis* from previous MBA marina surveys (pale blue), plus new marina records (mid-blue) and new shore records (red) from the EMFF surveys. Map imagery: Google Earth, © 2019 TerraMetrics.

3.4.5. Miscellaneous species observations

During the surveys, some instances were observed of one AS living on another as an epibiont, suggesting the possibility of facilitation of one AS by another. The bryozoan *Tricellaria inopinata* was seen relatively frequently on the brown alga *Sargassum muticum* (an apparent association also noted in Plymouth) (Figure 12). The colonial ascidians *Perophora japonica*, *Botrylloides diegensis* and *Didemnum vexillum* were noted growing on the unitary ascidian *Styela clava.*

The infaunal alien bivalves *Ruditapes philippinarum* and *Mercenaria mercenaria* were not systematically recorded during the shore surveys, since raking or digging of sediment was not undertaken, so that only a few incidental sightings of live animals were recorded. However, dead shells, typically along the strand line at the top of the shore, were recorded. Dead *R. philippinarum* was recorded on four of the 5 shores in which live specimens of the species were noted, but also on 15 additional shores. Dead shells of *Crepidula fornicata* and *Magallana gigas* were also frequently encountered but only recorded when no live animals at a site were noted; these dead records were submitted in Marine Recorder but not included in the analyses. It is important to note, however, that there is evidence in the Solent that areas of the subtidal substrate is being altered from predominantly mud to mixed shell communities because of high densities of *C. fornicata* shells (EMU Ltd., 2007; MESL, 2015).

The recently arrived small mytilid mollusc *Arcuatula senhousia* was recorded in the Marina of the River Test Cluster, but only as dead but still articulated shells. These were attached to shallowly submerged man-made surfaces, suggesting that the species could be spread at least locally by fouling yacht hulls, although transport in association with aquaculture or commercial shipping is more often suggested (e.g. Barfield *et al*., 2018).

Several specimens of the very small and infrequently recorded native caprellid amphipod *Caprella erethizon* were discovered in the lab amongst specimens of larger-bodied organisms brought back from shores on the Isle of Wight for identification. These were donated to the Natural History Museum, London, where the UK caprellids are being subjected to taxonomic revision, and detailed illustrations have been produced using the EMFF specimens.

3.5. Sites of interest:

The Marina site, Near shore site and Far shore site of the Hayling Island Cluster all had the highest count of AS of their particular site type (22, 21 and 18 respectively). Some otherwise infrequently recorded species were present at all three Hayling sites: *Hydroides dianthus* (only 8 occurrences in total across the 42 sites), *Didemnum vexillum* (10 sites), *Botrylloides violaceus* (13 sites) and *Bugula neritina* (17 sites). *Botrylloides diegensis* was recorded as abundant at all three Hayling sites but only at that level at two other sites in the entire data set. The marina in the Hayling Island Cluster also hosted one of only three records of the alien ascidian *Perophora japonica*.

In contrast to the Hayling Island Cluster, the River Test and Bembridge / Foreland Clusters hosted relatively low recorded AS biodiversity. The following widely encountered species remained unrecorded from the River Test Cluster: *Styela clava* (28 records across the 42 sites), *Tricellaria inopinata* and *Sargassum muticum* (27 records each overall) and *Botrylloides diegensis* (20 records). Nevertheless, two out of a total of five records of *Diadumene lineata* were in the R. Test, and the only encounter with *Arcuatula senhousia* (albeit involving dead shells) was in the Marina site.

The shore site at Seaview on the Isle of Wight had a surprisingly diverse set of ascidian species including some that were not, or were only rarely, recorded elsewhere during these surveys: the only record of the unitary AS *Asterocarpa humilis* and the colonial NS *Distaplia rosea* and one of only three records (including the nearby Ryde Beach site) of the AS *Perophora japonica*. Given that the marina in this cluster dries at low water and has low biodiversity, the source of this ascidian assemblage requires investigation.

3.6. Artificial substrates

All of the shores surveyed had some artificial substrate present. The relative percentage of the substratum was recorded on the MNCR forms. This consisted of fixed structures such as piers, pipes, sea defences, wooden posts, groynes and concrete boat moorings, as well as more mobile materials such as builder's rubble, tyres, metal, wood or plastic sheeting, ropes, netting, or general small plastic debris (Figure 20).

When recording the presence of a species on a shore the substrate to which it was attached to or associated with was recorded. All artificial substrate was included in a single category; other hard substrates noted were bedrock, boulders and cobbles/pebbles. However, it was often quite difficult to determine whether an object was naturally occurring or man-made, particularly with regard to identifying highly weathered concrete blocks as such and distinguishing naturally present vs. placed rock boulders. There were some inconsistencies in the recording of substrate (see Section 3.7 - Evaluation of Methodology) which means the data obtained is not sufficiently robust for a full data analysis. However, some broad observations were made:

Approximately 30% of records of species from hard substrates were recorded on artificial substrates.

The proportion of sessile animal AS settling on artificial substrate rather than natural hard substrate was greater than for sessile animal NS (33% compared to 28%).

The most common AS on artificial substrates were: *Austrominius modestus*; *Styela clava*; *Tricellaria inopinata*; and *Aplidium* cf. *glabrum*. Species that seemed to show a distinct preference for artificial hard substrate include: *Aplidium* cf. *glabrum*; *Botrylloides diegensis*; *Bugula neritina* and *Didemnum vexillum*.

Some NS also benefitted from the presence of increased hard substrate, those we recorded most frequently on artificial hard substrate being: *Ascidiella aspersa*; *Hymeniacedon perlevis*, *Mytilus* spp. and *Semibalanus balanoides*.

Figure 20: Plastic debris on the mixed-sediment soft shore at TAL SHR, with a dense array of ascidians and bryozoans.

3.7. Fisheries and biosecurity

In the 12 complete clusters, the Pacific oyster *Magallana gigas* was recorded live at 19 out of 36 sites (Figure 21). Of these, four records were of Frequent-common abundance and five Abundant-superabundant. All of the records above Rare-occasional were in Southampton

Water or in the adjacent lower reaches of the Rivers Test, Itchen and Hamble (Figure 22). The densest population encountered was at MCH SHR in the River Test Cluster. In the remaining two clusters (i.e. Bembridge/Foreland and Ryde/Seaview), *M. gigas* was recorded at a single additional site, RYD SHR, as Rare-occasional – the only Isle of Wight record of the species in these surveys.

The native oyster *Ostrea edulis* was recorded live at 21 out of 36 sites in the 12 clusters (Figure 21). No large accumulations of the species were noted, and the species was always recorded as Rare-occasional (Figure 22). (*O. edulis* was not recorded in the two remaining clusters.) This species is the subject of the Solent Oyster Recovery Project led by the Blue Marine Foundation. In addition to the potential threat from Pacific Oyster dominance, the recovery of *O. edulis* might be compromised by competition/interference from the alien suspension-feeding gastropod *Crepidula fornicata* (Slipper Limpet). Although *C. fornicata* was seen in 50% of the sites during all the surveys, subtidal populations tend to be much more significant, and are separately monitored by Natural England. A further threat, particularly to young individuals, is predation. A variety of species prey on native oysters especially oyster-drill gastropods, native (*Ocenebra erinaceus*) and potentially alien (*Urosalpinx cinerea* or *Ocinebrellus inornatus*) species. No alien oyster drill was identified during the present surveys. *O. erinaceus* was unrecorded in marinas but was fairly frequent on shores, being reported from 16 of the 28 shores surveyed in total, although never categorized as abundant.

A further potential danger to bivalve shellfish beds is smothering by the sheet-like alien colonial ascidian *Didemnum vexillum*. The colonisation, noted elsewhere, of open Solent shores by this species formerly limited to marinas could presage its spread onto the open seabed, with possible impact on subtidal bivalve populations (e.g. Kaplan *et al.*, 2017).

The considerable prevalence of alien marine invertebrates and algae in the Solent, documented here, could result in increased fouling of commercial fishing vessels (and recreational vessels), with attendant increased fuel and maintenance costs. Any costs of biosecurity measures in response to the threat posed by present or future bioinvasions would also be partly borne by the fishing and aquaculture industries.

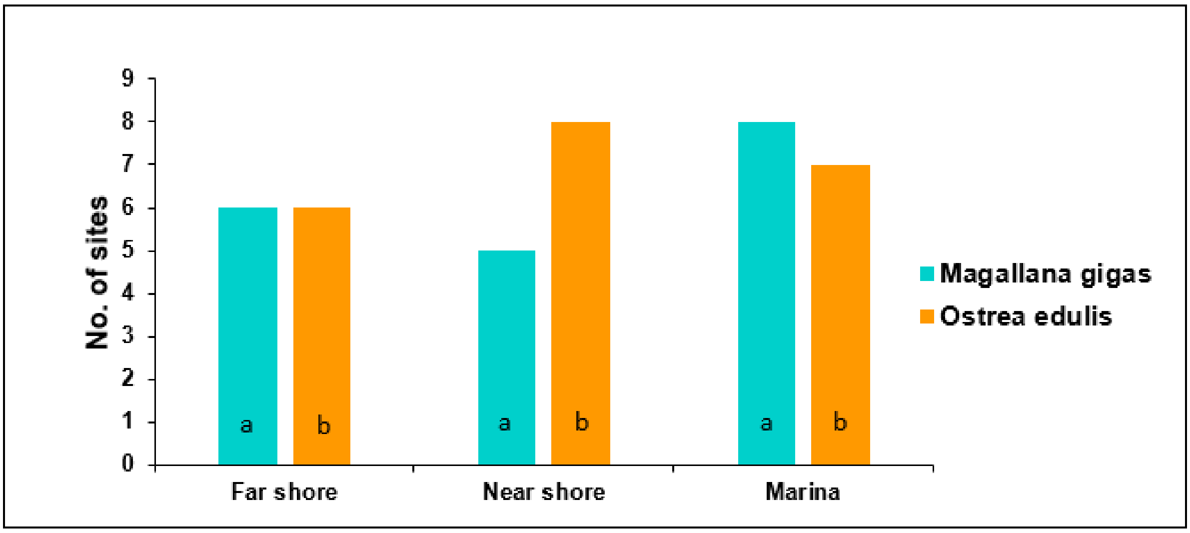


Figure 21: Occurrences of the oysters *Magallana gigas* (a, blue) and *Ostrea edulis* (b, orange) in the three site types: Far shore, Near shore and Marina.

Figure 22: Occurrence (live) and estimated abundance of the oysters *Magallana gigas* (red) and *Ostrea edulis* (green), at shore and marina sites in the Solent. Small circles indicate Rare-occasional abundance, medium circles indicate Frequent-common, large circles indicate Abundant-superabundant; split small circles indicate both species present as Rare-occasional. Map imagery: Google Earth, © 2019 TerraMetrics.

4. DISCUSSION

4.1. Résumé of findings

Rapid assessment surveys detected numerous AS both in marinas and on shores, the great majority of species being recorded in both habitats. The maximum number of AS recorded per site was 22 for Marinas, 21 for Near shores and 18 for Far shores. Marina sites held on average 4.4 more AS than the Near shore in the same Cluster, but Near shores had on average 3.5 more AS than the equivalent Far shore. Accordingly, the recorded ratio of AS to NS was significantly higher overall in Near shores than in the matching Far shores. The average per-species occupancy of sites by AS (i.e. the frequency of a species' occurrence) declined in the same order, Marina to Near shore to Far shore, but no such trend was apparent amongst the NS surveyed. Approximately 13 AS for which there are presently no shore records for the Solent in the NBN Atlas were detected on the shore. Amongst these were the bryozoan *Watersipora subatra*, which has already achieved considerable densities on shores further west in England, and the colonial ascidian *Didemnum vexillum*, considered nationally to be a substantial threat to economic interests and native biodiversity. The bryozoan *Tricellaria inopinata* and the colonial ascidian *Botrylloides diegensis* were found to be widespread and frequent on Solent shores. Man-made substrates on otherwise natural shores appeared to promote the presence of both AS and some NS.

4.2. Alien species diversity

The high number of AS in marinas, with lower numbers on nearby shores declining further with distance, strongly suggests exchange between marinas and shores, with the 'leakage' of AS from marinas onto shores the most likely scenario. The declining prevalence of AS with distance from a marina is reflected in the parallel reduction in the ratio of AS to NS. The ratio of AS to NS has been suggested as an indicator to assess environmental status. Marinas appear to have a detectable effect on this measure in Natura 2000 sites in the Solent.

The ANOSIM results indicate that the various clusters of sites are somewhat differentiated in terms of AS assemblage composition, irrespective of differences between site types. The clear multivariate distinction between Marina and Shore sites but lack of distinction between the Near shore and Far shore site types according to ANOSIM is demonstrated in the MDS plot, in which the two types of shore site are intermingled, although with the Near shore sites somewhat less scattered and closer overall to the Marina sites.

4.3. Site occupancy by AS

The overall pattern of decline in site occupancy by AS from marinas to nearby shores to more distant shores is not shown by NS in this study, and is thus peculiar to the AS. This pattern would be expected if AS were in the process of spreading by incremental dispersal from the artificial habitat of marinas into natural habitats. This process seems to have occurred in the case of the Asian kelp *Undaria pinnatifida* studied on the south coasts of Devon and Cornwall by Epstein & Smale (2017). At the time of the study, the species was present in all the marinas but only 50% of natural rocky reefs in the study areas. The probability of presence of *U. pinnatifida* at a natural site increased with proximity to a marina with a large population of the kelp and with the inferred propagule pressure from the local marina population(s), strongly indicating a pattern of initial colonisation of reefs by 'spillover' from local marinas. However, a variant scenario, under a metapopulation model, for the general pattern of AS occupancy observed in the present study might be that AS populations in marinas in general undergo fewer local extinctions and/or more rapid re-establishment than on shores, and possibly thereby have a role in periodically re-seeding local patches of shore that have fallen vacant. In this scenario, marinas act as relatively benign habitats for AS, which may have an important role in supporting the long-term presence of AS on natural shores, perhaps by bridging a substantial low-population lag-phase on natural shores, possibly with periodic extinctions, but sometimes leading to longer-term establishment.

The absence of a decline in site occupancy between Near and Far shores amongst NS indicates that the contrasting decrease in AS is not caused by general environmental differences, affecting all species, between the two shore categories. Rather, the decline relates to an AS-specific factor driven by differences in proximity to a Marina. 'Leakage' of AS from the marinas onto nearby shores, with less effect on more distant shores, appears the most likely explanation.

The highly significant correlation of species' occupancy levels of marina and shore sites by both AS and NS indicates that the rank-order of occupancy amongst species stays relatively similar between Marina, Near shore and Far shore sites.

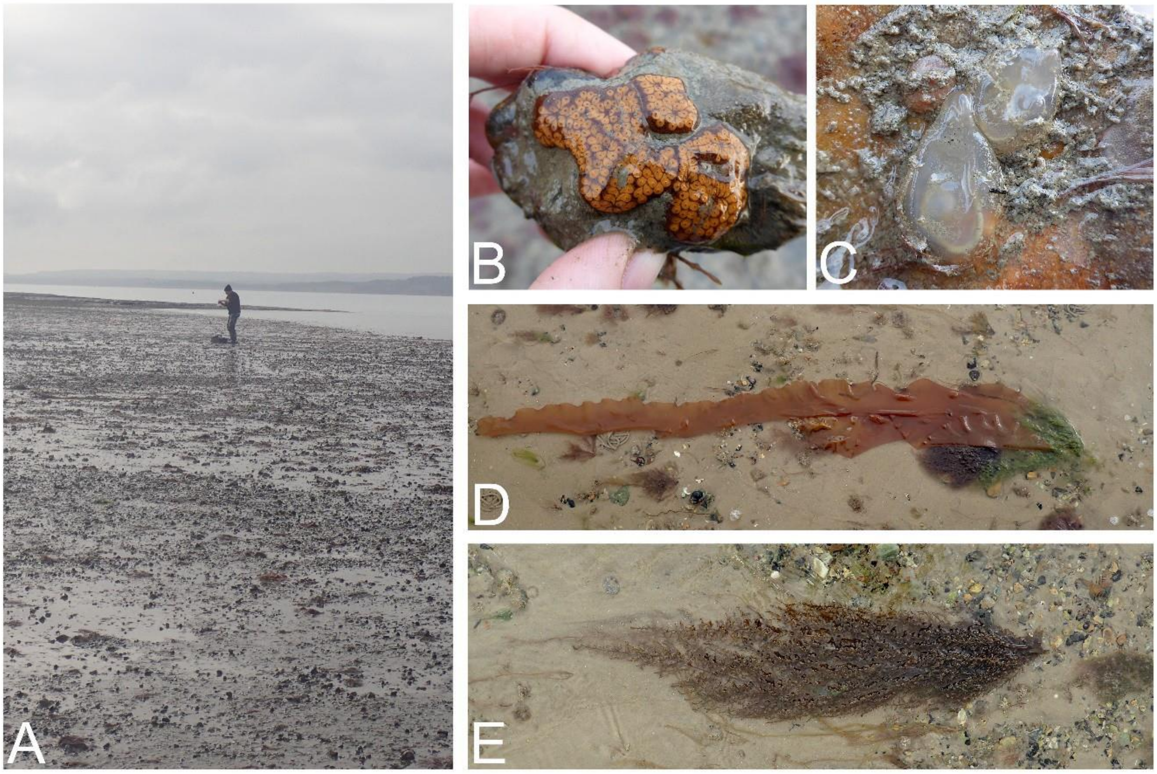


Figure 23: Mixed-sediment soft shores on the Solent can appear unpromising (**A**: TAL SHR, 18/05/2018), but can host a substantial diversity of sessile biota, often on relatively small natural substrates such as pebbles (**B**: the alien ascidian *Botrylloides diegensis*) but also commonly on any man-made structures or debris (**C**: the alien ascidian *Corella eumyota* on plastic debris); both examples from TAL SHR, where 14 living AS were recorded. Macroalgae also attach to small stones and pebbles, which can then become buried (**D**: *Grateloupia turuturu*, **E**: *Sargassum muticum*, both alien, STP SHR, 20/05/2019).

4.4. Artificial substrates

The presence of hard substrate on shores, which are otherwise predominantly made up of sand or mud, provides additional habitat niches that can be exploited by other species. Therefore, the introduction of artificial material onto a shore where there is little natural hard substrate (quite common in the Solent area) can lead to changes in biodiversity, particularly with regard to sessile species such as ascidians, bryozoans and serpulid worms. The traits associated with the success of IAS—rapid reproduction, fast growth, and tolerance of a wide range of environmental conditions—mean that newly introduced hard substrate on a shore can rapidly become colonised by IAS. In addition, the connectedness of a coast may be increased by the introduction of artificial hard substrate, providing stepping-stones in otherwise inhospitable environments, exacerbating the spread of IAS.

4.5. The Solent in context

In the present study, marinas in the Solent have been found to host up to 22 AS of (mostly sessile) animals and macroalgae per site, and to be associated with an increased number of AS on nearby Natura 2000 shores. RASs in 2014-16 surveys of marinas and harbours around the entire English and Welsh coasts, with a slightly reduced target list of sessile animals and algae, showed the Solent to be an area of relatively high AS diversity (including the highest site-count registered, at 19 AS), but the general levels of colonisation were also high in some other regions, with 14 or more AS recorded at 15 additional sites, mostly in SW England and East Anglia (Figure 24; Wood *et al.,* 2015 a and b; 2016; 2017). The Solent has the largest collection of marinas in the UK, but other clusters occur, particularly on the English Channel coast of SW England. For instance, Plymouth has eight marinas in the Plymouth Sound and Estuaries SAC. It thus seems likely that the influence of marinas on natural shores reported here is not unique to the Solent: other shores could be similarly affected, and many of these would be in Natura 2000 sites.

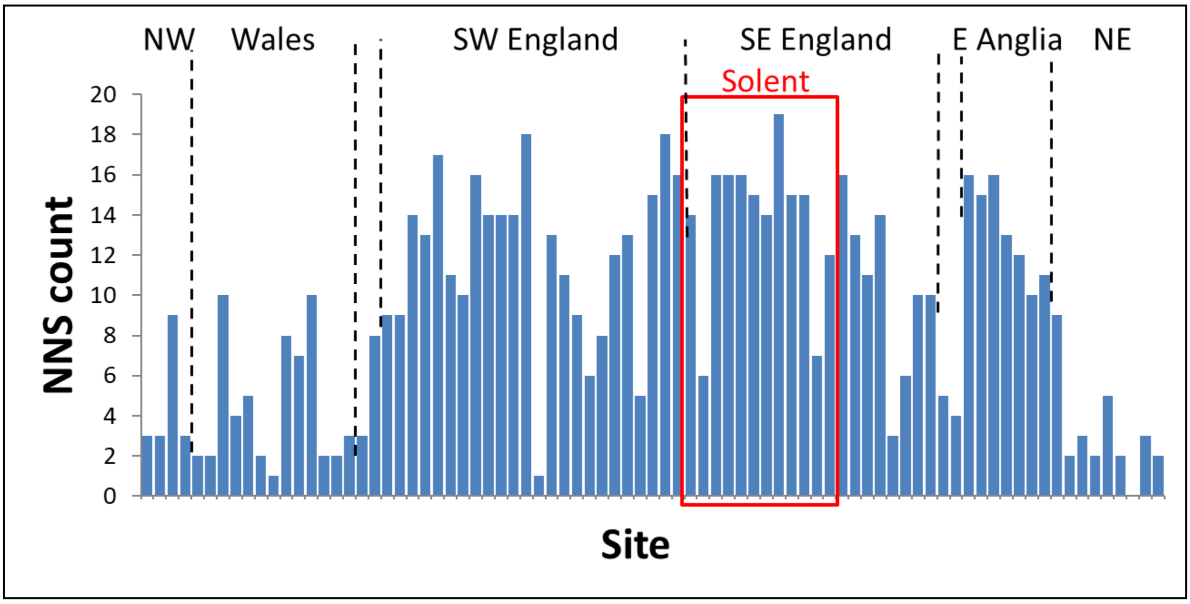


Figure 24: Counts of AS in RAS surveys of marinas and harbours around the entire English and Welsh coasts in 2014-16. Data from 81 sites is presented from NW England anticlockwise to NE England. The 12 Solent sites included (Lymington to Southsea) are indicated in red. Funding from the Bromley Trust and Natural England gratefully acknowledged by the MBA.

4.6. Evaluation of protocols

On completion of the Year 1 surveys, an evaluation was made of the efficiency and ease of use of the shore survey methodology. Modifications were made to:

- The method for determining the geographical coordinates of the area surveyed.
- The Shore Summary Form, which was altered to ease input into Marine Recorder.

- Weather recording, specific scales being adopted rather than general comments.
- The target lists for AS and NS, which were modified slightly.

These changes were successfully implemented in Year 2.

4.6.1. Effectiveness

The very high numbers of AS detected on a wide variety of shores, many for the first time in the region, as reported in Section 3.1, offers clear evidence that the method is effective in detecting AS. Figure 11 illustrates this for the bryozoan *Tricellaria inopinata*, showing the limited intertidal records currently held on NBN Atlas, compared with those found during these surveys.

The Shore protocol was adapted from the Rapid Assessment Survey protocol that has been used very effectively to survey marinas and harbours for many years (Cohen *et al*., 2005; Pederson *et al*., 2005; Arenas *et al*., 2006; Bishop *et al*., 2015) We were unsure when designing the protocol whether limiting the survey to 1 h around low water would be sufficient to capture adequately the range of AS present in the more complex and less accessible shore habitat. An assessment of the adequacy of the one-hour search interval was made by checking whether the rate of discovery of new taxa had fallen to a very low level by the fourth15-minute interval. Figure 25 shows that this is the case and that there is no appreciable difference between the detection rates from use of the marina and shore protocols.

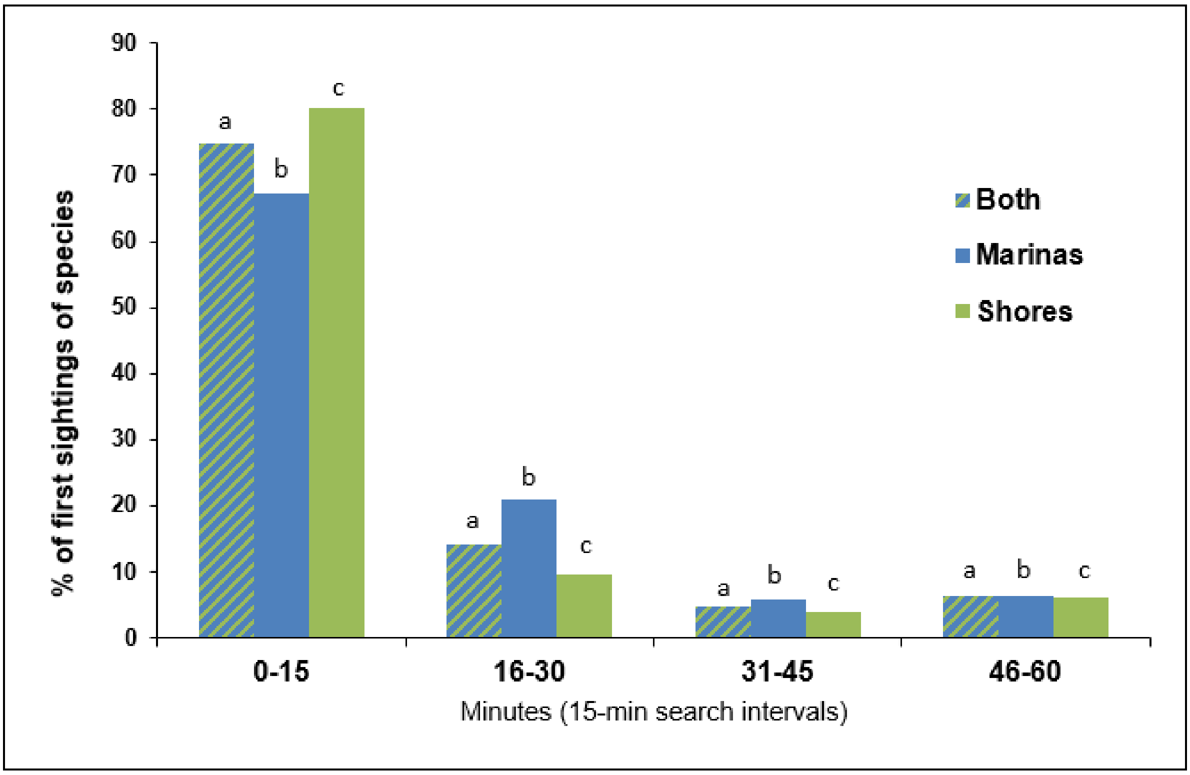


Figure 25: Percentage of first encounters of a target species, recorded by any surveyor, at all Marina and Shore sites, during each 15-minute interval. Left to right: a = both, b = marinas, c = shores.

As discussed in Section 3.3.5 this protocol is not suitable for the detection of infaunal species, although some were noted during the surveys.

4.6.2. Ease of use

The surveying of shores as compared to marinas or harbours does inevitably require more detailed planning e.g. identification of suitable shores and access points, determination of land ownership, site-specific health and safety considerations, and determination of tidal heights and times.

For Marina site surveys two recording forms were used, a Marina Survey Recording Form for use during the 1 h survey and then a Summary Marina Survey Form containing the combined information from all surveyors, preservation details and environmental measurements. For Shore surveys, two additional forms were included: The Shore Environmental Recording Form detailing tidal, weather, geographical, and health and safety details; and the MNCR form describing the habitat features. Other than the geographical information, neither of these extra forms is essential to the detection of AS. However, they are of use to Natural England for the monitoring of protected areas and planning future surveys.

The Shore Survey Recording Form used during each survey was more complex than that used for Marinas, mainly as it required the recording of substrates on which species were found. Again, this information is of particular interest to Natural England who have responsibility for specific habitat features. Some minor modifications to the substrate options could also be made to provide clarity and better capture artificial substrates.

The method could also be simplified by reducing the number of native species actively recorded. They are included to provide insight into the habitat of a shore and to allow comparison of AS:NS ratios between sites, but again, this data may not be required for a particular set of surveys.

As it stands, users of the shore protocol and the Shore Survey Recording Form would need training and detailed written instructions to ensure a common standard for substrate identification and recording. The method works best when a surveyor is accompanied by a scribe or second observer, to better ensure all the information is captured. Any simplification of the protocol should be applied to a complete set of surveys to ensure comparability of the data.

4.7. Target species lists

For this project target lists of 50 AS and 57 NS were used. Many of these species require microscopic examination and/or taxonomic expertise to confirm their identification. Some species may also require DNA sequencing. These are not practical options for many surveys, especially for those carried out by volunteers/citizen scientists, or where field identification is all that is possible. In addition, the region and habitat types being surveyed are relevant in determining which species should be included on a target list.

If it is possibly more important to document new arrivals rather than AS already known to be present locally, any AS target list should include ‘near-horizon species’ present elsewhere in the UK and ‘far-horizon species of particular concern.

Thus, we suggest that project-specific target lists should be developed, using expert guidance, to meet the specific needs of a project, taking into account purpose, region, surveyor skill levels, access to laboratory facilities, and taxonomic expertise.

Two sample target lists are included at Appendix XI, both suitable for use in the Solent region. They have been designed to detect those AS most likely to affect the ecosystem and thus a site’s environmental status. They include marine species that are already established in the region and other horizon species that are either present elsewhere in the UK or in Europe that are likely to have an impact. List A could be used by experienced surveyors with some access to additional resources e.g. taxonomic support and/or a microscope. List B relies completely on field identification by non-professionals but who have received some training and resources e.g. descriptions and images of AS, and likely confusion species.

4.8. Future sites: Suggestions of sites for future monitoring/surveillance

Deciding on the best sites for future monitoring is dependent on the main purpose of the monitoring. Below are detailed a number of different approaches.

4.8.1. Monitoring of specific sites with already high numbers of AS

These sites already have high numbers of AS, so show evidence of a connection to a source of AS, which may be traffic related, so monitoring the shipping, boat movements etc. may also be relevant and inform site choice. Suggestions based on this criterion are:

Shores: NOR SHR, OYS SHR, HKS SHR, NET SHR, NSP SHR,

Marinas: NOR MAR, HAP MAR, CYH MAR, YAR MAR, SOU MAR, OCN MAR, SPK MAR

4.8.2. Monitoring with broad geographical coverage

Selecting sites from across the region to ensure good geographical coverage, combined with high numbers of AS. Thus, sites would be included from Lymington, Southampton Water, Isle of Wight, Portsmouth Harbour, Chichester Harbour and Langstone Harbour.

4.8.3. Monitoring by Cluster

In this approach the Marina/Near/Far shores relationship is maintained, so spread from a specific source can be monitored. One possibility is to select the five Clusters with the highest numbers of AS. This approach could be combined with geographical coverage, so the best Clusters within different regions are monitored. Suggested Cluster choices are: Yarmouth/Norton, Medina, Hamble Estuary and Hayling Island.

4.8.4. Monitoring spread of specific species

The spread of *Didemnum vexillum* onto shores is of concern; this has already occurred in the Hayling Island and Chichester Harbour Clusters, so monitoring of impact at these sites may be important. There are other areas (Yarmouth/Norton, Medina and Hamble Estuary) where *D. vexillum* is present in the Marina but has not yet been recorded on the adjacent shores; these should be monitored to check for future break-out.

4.8.5. Unidentified source populations

There are a number of AS found at Seaview for which there is no obvious source, and investigations of traffic flow may be useful in this context, to identify alternative vectors.

4.9. How were the aims achieved?

This project had 12 key aims as identified in Section 1.1. Below is a brief description of how each aim was achieved.

1. Develop a new rapid protocol for surveys of IAS within intertidal areas such as those of the Solent Maritime SAC. The methodology will be replicable for future Solent surveys and used elsewhere in England

A new protocol has been tested and modified over two years at 14 marina sites and 28 shore sites across the Solent. Further trials have been conducted outside of the scope of this report both within Solent as training days and in Devon and Cornwall through further surveys by The Bishop Group. The methodology will be shared with staff from across Natural England on a training day in June 2020 which will allow the methodology to be rolled out across sites elsewhere in England. In addition, the methodology has been presented to stakeholders across Solent at a Hampshire Non-Native Species Group Meeting and will be presented, alongside the findings of this report, at a future Solent Forum meeting to all key stakeholders in the Solent.

2. Survey IAS at a series of locations each comprising a marina/harbour and two adjacent natural shores.

Surveys have been conducted at 14 marina sites and 28 adjacent shore sites (one Near and one Far). By selecting a shore site near to a marina and then further away it has allowed for further analysis as to the potential spread of IAS.

3. Analyse resulting data and information from previous Marine Biological Association (MBA) surveys to elucidate the risk of spread of IAS from marina / harbour populations onto adjacent natural shores and impact on associated fisheries operations, considering both individual species and the overall risk

This report has provided full analysis of results in section 3.

4. Provide better and more robust data that will increase understanding of IAS, their impacts and the feasibility of undertaking control and different management options.

This study has provided the first comprehensive study of IAS within Solent. It is the first to survey marinas and accompanying shores to allow for a thorough assessment of presence, spread and colonisation risk. The data generated form this report will form the baseline for future monitoring to allow for effectiveness of any control or eradication methods to be tested.

5. Provide data to help communicate the scale of risks to different maritime sectors (e.g. aquaculture) who are responsible for managing the different IAS pathways

Site-specific species lists, an example of which is shown at Appendix XII, have been sent to every landowner to help them better understand IAS present at marinas / harbours they own or land they manage. In addition, the findings of this report will be presented at a future Solent Forum meeting to all key stakeholders in the Solent.

6. Develop and inform suitable and feasible management actions and best practice to minimise the spread of IAS within the region. The final report will inform, promote and help relevant harbour authorities to improve biosecurity plans

Site-specific species lists have been sent to every marinas / harbour master. As a result of these surveys a biosecurity plan is already in preparation for North Solent National Nature Reserve. MDL marinas, a large marina operator in the Solent is also using this data to help inform the biosecurity plans that they are already putting in place. In addition, the findings of this report will be presented at a future Solent Forum meeting to all key stakeholders in the Solent.

7. Encourage collaboration between public bodies (Natural England, IFCAs, Cefas and MMO), local harbour authorities, IAS specialists from the MBA, and local fishermen and foster liaison on best practice to minimise the spread of IAS within the region

The work has involved collaboration between Natural England, IAS specialist from MBA, local harbour authorities and landowners through delivery of the grant. Water and tissue samples were collected at various sites and provided to Marine Science Scotland for use in a separate project seeking to test whether eDNA could be used to monitor presence of IAS. In addition, the findings of this report will be presented at a future Solent Forum meeting to all key stakeholders in the Solent.

8. Use baseline data to inform future policy work

This data will be used as a baseline of IAS presence and spread risk in Solent. Full detail as to how this data will inform future policy work is also provided in Section 5.

9. Develop a target list of IAS for future monitoring within the Solent

Two target lists of IAS for future monitoring in Solent have been developed as part of this project. The first is aimed at Professional staff and will be used for all future monitoring of IAS in Solent. The second is a reduced list only including those species easily identifiable in the field and is aimed at Volunteers or Citizen Scientists. Both lists are shown in Appendix XI.

10. Train Natural England staff on intertidal and marina rapid survey protocols and IAS identification, improving the identification and surveying skills of up to 30+ people

Over 30 members of Natural England staff used their learning and development days to accompany the core survey team over the 2 years of survey. Each member of staff was actively involved in the survey effort and was provided with an IAS identification guide to take home to allow for continued skills development. In addition, a further training day is planned for staff from across Natural England in June 2020 which focus specifically on teaching the new protocol developed as part of this work alongside IAS identification in the field.

11. Raise awareness amongst marina/harbour staff of IAS as an environmental threat and provide information on the IAS present at their site to assist biosecurity planning

Every marina / harbour master was invited to accompany the survey team on the day of survey. In addition, each were provided with at least one copy of an IAS guide for future monitoring. Site-specific species lists have also been sent to every marinas / harbour master.

12. Make IAS distribution data publicly available via NBN Atlas.

All data has been added onto Marine Recorder and provided to NBN Atlas to be included in the next update.

5. CONCLUSIONS AND APPLICATION OF RESULTS

5.1. Applicability to The Marine Strategy Part 1: UK updated assessment and Good Environmental Status Report

A recent MSFD-driven document, *The Marine Strategy Part 1: UK updated assessment and Good Environmental Status Report*[1], details the first UK-wide assessment of the status of Non-Indigenous Species (NIS) based on trends of new introductions over time. The results suggested that there has been no significant reduction in the risk of introduction over time, but with low confidence because of a paucity of relevant data. It is acknowledged that monitoring and surveillance in order to detect introductions, particularly at high-risk locations, needs to be improved. Spread of NIS is also a key characteristic of GES within the MSFD that has notyet been assessed. The new rapid protocol for shore surveys developed during this EMFF project is a targeted methodology that could be adopted for future monitoring programmes and thereby address this lack of data. The method appears efficient, and our data show, to agreater degree than previously documented, that AS are invariably present, and sometimes prevalent, in natural intertidal habitats of Natura 2000 sites in the Solent.

5.2. Natura 2000 shores

Although the shore surveys reported here revealed a substantially greater presence of AS on Solent shores than previously documented, AS are not commonly present in sufficient numbers at Natura 2000 sites to have an apparent serious effect on the native biota. However, some IAS did cause concern at a number of sites, for instance: *Sargassum muticum* amongst *Zostera* beds e.g. at NSP SHR and BRL SHR; *Magallana gigas* forming dense aggregations on shores in the Test and Itchen clusters.

The previously unrecorded occurrence of *Didemnum vexillum* on the shores of the Solent, most frequently in the eastern section, is of concern given the species' potential impact shellfish culture, and its propensity to cover large areas of seabed. *D. vexillum* also poses a potential threat to seagrass beds and was first recorded growing on *Zostera marina* in NE USA (Carman & Grunden, 2010). Subsequently, Long & Grosholz (2015) demonstrated that overgrowth of *Z. marina* blades in California by *D. vexillum* reduced the above-ground growth of seagrass shoots. A reduction in seagrass growth due to light reduction has also been observed as a result of fouling by other invasive ascidians (McKenzie *et al*., 2017 and references therein).

The arrival in the Solent of *Arcuatula senhousia* as a species new to the UK emphasises the potential of the area for hosting new arrivals and is of concern given the species' ability to reach very high densities and form byssal mats on sedimentary shores and the seabed (Mistri & Munari, 2013). Its occurrence attached to solid surfaces at one marina in the present surveys suggests the potential for recreational boating to act as a vector for this species.

Our observations suggested that artificial objects and fixed structures, frequently derelict, in otherwise natural sites disproportionately influenced the roster of AS and to some extent NS. Most of the significant aggregations of AS on 'natural' shores were in fact associated with artificial structures. This arguably reduces the environmental status of the shores and promotes further spread of AS. Management options that might be considered are prevention of addition of more objects, plus the removal of existing portable items such as tyres, abandoned fishing gear and building debris, especially from low on the shore, and the targeted removal of fouling growth from fixed artificial structures.

[1] https://www.gov.uk/government/publications/marine-strategy-part-one-uk-updated-assessment-and-good-environmental-status

5.3. Biosecurity planning

This project addresses a lack of knowledge of the nature and scale of risk from IAS in the Solent that limits the marine sector's ability to take proactive management action. The information provided will assist operators in marine sectors such as aquaculture, fisheries, transport, and recreational boating in the development of operator-specific, site-specific and area-wide biosecurity plans, building on plan development tools such as those provided by RAPID LIFE (2019a). The present EMFF project provided site-specific lists of AS and species identification guides to operators; this knowledge of the actual species that they are likely to encounter and the likely threats will help operators to understand the importance of biosecurity planning and to tailor their plans to their own area.

The GB Non-Native Species Secretariat is currently working on a Pathways Action Plan with key national stakeholders for recreational boating to raise awareness and facilitate the adoption of good biosecurity practice in this sector. The Solent project demonstrated that marinas have higher numbers of AS than shores, but have a local 'halo' of increased AS presence and thus appear to play an influential role in the establishment of AS on natural shores. This evidence demonstrates the key role of marinas as a source of IAS for further spread, which will add further incentive to delivering the actions outlined in the Pathways Action Plan at a national level. The findings with regard to marinas can also be used to illustrate the potential role of infrastructures in other marine economic sectors in the spread ofIAS, thereby promoting further biosecurity plans and implementation of good practice to prevent the spread of IAS.

5.4. Additional data uses:

- Inform future condition assessments for Solent Maritime SAC;
- Inform future assessment of progress towards Descriptor 2 of Good Environmental Status (2024);
- Add to our general understanding of IAS and the knowledge base of different species characteristics. This will be useful to inform future policy work such as action plans led by the GB Non-Native Species Secretariat e.g. *D. vexillum* and any future Species Risks Assessments;
- Inform any future reviews of the Regional Invasive Management Plans (RIMPS) (RAPID LIFE 2019b) that were developed by the RAPID LIFE project and will be kept up to date by APHA; and
- Improve our capacity to monitor the effects of the International Ballast Water Convention, by providing a baseline of IAS within the Solent Maritime SAC.

6. REFERENCES

Arenas, F.F., Bishop, J.D.D., Carlton, J.T., Dyrynda, P.J., Farnham, W.F., Gonzalez, D.J., Jacobs, M.W., Lambert, C., Lambert, G., Nielsen, S.E., Pederson, J.A., Porter, J.S., Ward, S. & Wood, C.A. 2006. Alien species and other notable records from a rapid assessment survey of marinas on the south coast of England. *Journal of the Marine Biological Association of the United Kingdom*, 86: 1329–1337.

Barfield, P., Holmes, A., Watson, G. and Rowe, G. 2018. First evidence of *Arcuatula senhousia* (Benson, 1842), the Asian Date Mussel, in UK waters. *Journal of Conchology*, 43(2), pp.217-222.

Bishop, J.D.D., Wood, C.A., Yunnie, A.L.E., Griffiths, C.A. 2015. Unheralded arrivals: non-native sessile invertebrates in marinas on the English coast. *Aquatic Invasions* 10(3): 249-264. doi: http://dx.doi.org/10.3391/ai.2015.10.3.01

Carman, M.R. |& Grunden, D.W., 2010. First occurrence of the invasive tunicate *Didemnum vexillum* in eelgrass habitat. *Aquatic Invasions*, 5, pp.23-29.

Cohen, A.N., Harris, L.H., Bingham, B.L., Carlton, J.T., Chapman, J.W., Lambert, C.C., Lambert, G., Ljubenkov, J.C., Murray, S.N., Rao, L.C., Reardon, K. & Schwindt, E. 2005. Rapid assessment survey for exotic organisms in southern California bays and harbors, and abundance in port and non-port areas. *Biological Invasions* 7: 995–1002

Dyrynda, P.E.J., Fairall, V.R., Occhipinti Ambrogi, A. & d'Hondt, J.L. 2000. The distribution, origin and taxonomy of *Tricellaria inopinata* d'Hondt and Occhipinti Ambrogi, 1985, an invasive bryozoan new to the Atlantic. *Journal of Natural History*, 34:1993-2006.

EMU Ltd. 2007. Survey of the Subtidal Sediments of the Solent Maritime SAC. Report to Natural England

Epstein, G., & Smale, D. A. 2017. *Undaria pinnatifida*: A case study to highlight challenges in marine invasion ecology and management. *Ecology and Evolution*, 7(20), 8624-8642.

European Commission 2008. Directive 2008/56/EC of the European Parliament and of the council of 17 June 2008 establishing a framework for community action in the field of marine environmental policy (Marine Strategy Framework Directive). Official Journal of the European Communities L164, 19 (25.06.2008).

Kaplan, K.A., Hart, D.R., Hopkins, K., Gallager, S., York, A., Taylor, R. & Sullivan, P.J. 2017. Evaluating the interaction of the invasive tunicate *Didemnum vexillum* with the Atlantic sea scallop *Placopecten magellanicus* on open and closed fishing grounds of Georges Bank. *ICES Journal of Marine Science*, 74(9), pp.2470-2479.

Long, H.A. & Grosholz, E.D. 2015. Overgrowth of eelgrass by the invasive colonial tunicate *Didemnum vexillum*: consequences for tunicate and eelgrass growth and epifauna abundance. *Journal of Experimental Marine Biology and Ecology*, 473, pp.188-194.

McKenzie, C.H., Reid, V., Lambert, G., Metheson, K., Minchin, D., Pederson, J., Brown, L., Curd, A., Gollasch, S., Goulletquer, P., Occhipinti-Abbrogi, A., Simard, N. & Therriault, T.W. 2017. Alien Species Alert: *Didemnum vexillum* Kott, 2002: Invasion, impact and control. [online] ICES Cooperative Research Report. Available from:

https://pdfs.semanticscholar.org/1567/93c5565cef298384a8e64c9875330e1d84e9.pdf [Accessed 03/02/2020]

Mistri, M. & Munari, C., 2013. The invasive bag mussel *Arcuatula senhousia* is a CO_E generator in near-shore coastal ecosystems. *Journal of Experimental Marine Biology and Ecology*, 440, pp.164-168.

MESL (Marine Ecological Surveys Ltd.). 2015. Solent Maritime European Marine Site sandbank habitat mapping project. Report to Natural England. Report No. RP02543 available from http://publications.naturalengland.org.uk/publication/5700835531554816 [Accessed 20/12/2019]

Pederson, J., Bullock, R., Carlton, C., Dijkstra, J., Dobroski, N., Dyrynda, P., Fisher, R., Harris, L., Hobbs, N., Lambert, G., Lazo-Wasem, E., Mathieson, A., Miglietta, M-P., Smith, J., Smith, III J. & Tyrrell, M. 2005. Marine invaders in the northeast: rapid assessment survey of non-native and native marine species of floating dock communities. Report of the 3-9 August 2003 survey. MIT Sea Grant College Program, Cambridge, Massachusetts, USA, 40 pp

RAPID LIFE. 2019a. RAPID INNS Management Toolkit: Marine Biosecurity Resources available at https://www.nonnativespecies.org/biosecurity/marine-biosecurity/ [Accessed 20/12/2019]

RAPID LIFE. 2019b. RAPID INNS: Regional IAS Management Plans (RIMPs) available from https://www.nonnativespecies.org/local-action-groups-lags/rapid-life-project/regional-ias-management-plans-rimps/ [Accessed 20/12/2019]

Thorp, C.H., Pyne, S. and West, S.A. 1987. *Hydroides ezoensis* Okuda, a fouling serpulid new to British coastal waters. *Journal of Natural History*, 21(4), pp.863-877.

Ulman, A., Ferrario, J., Forcada, A., Arvanitidis, C., Occhipinti-Ambrogi, A. & Marchini, A. 2019. A Hitchhiker's guide to Mediterranean marina travel for alien species. *Journal of Environmental Management*, *241*, p.328.

Williams, F., Eschen, R., Harris, A., Djeddour, D., Pratt, C., Shaw, R.S., Varia, S., Lamontagne-Godwin, J., Thomas, S.E. & Murphy, S.T. 2010. The Economic Cost of Invasive Non-Native Species on Great Britain. DEFRA commissioned report from CABI.

Wood, C.A, Bishop, J.D.D. & Yunnie, A.L.E. 2015. Plotting the current distribution of NNS in English marinas. Natural England Report for Grant ECM_6501.

Wood, C.A., Bishop, J.D.D. & Yunnie, A.L.E, 2015. Comprehensive reassessment of NNS in Welsh marinas. Report to Natural Resources Wales. 42pp https://core.ac.uk/download/pdf/78761493.pdf?msclkid=f0878450bb3311ecbb04ff69d4f19f4f

Wood, C.A., Bishop, J.D.D., Rennocks, L. & Crundwell, R. 2016. Non-native species rapid assessment surveys in English marinas (E Anglia & W coast). Report to the Bromley Trust. 41pp https://core.ac.uk/download/pdf/78761494.pdf?msclkid=1a9902a3bb3411ecaae2f199ea14f8cd

Wood, C.A., Bishop, J.D.D., Nall, C.R. & Rennocks, L. 2017. Non-native species rapid assessment surveys in English marinas (NE & SW coasts). Report to the Bromley Trust. 39pp https://core.ac.uk/download/pdf/96667124.pdf?msclkid=4b6936e4bb3411ecb5230c06299079f2

Zibrowius, H. 1978. Introduction du polychète Serpulidae japonais *Hydroides ezonesis* sur la côte atlantique française et remarques sur la répartition d'autres espèces de Serpulidae. *Tethys*, 8, pp.141-150.

Appendix I: Details of sites surveyed

Site Code	Site	Coordinates (WGS84)		Date of Survey
		Latitude	Longitude	
FTV SHR	Fort Victoria, Isle of Wight	50.704858	-1.524656	16/05/18
NSP SHR	Norton Spit, Isle of Wight	50.705770	-1.506207	17/05/18
YAR MAR	Marina / Harbour near Yarmouth, Isle of Wight			17/05/18
PKB SHR	Park Shore, New Forest	50.764182	-1.426995	17/05/18
TAL SHR	Tanners Lane, New Forest	50.755171	-1.479961	18/05/18
LYH MAR	Marina / Harbour in Lymington Estuary			18/05/18
GUB SHR	Gurnard Bay, Isle of Wight	50.761757	-1.322651	15/06/18
CTB SHR	Cowes Town Beach, Isle of Wight	50.766718	-1.302966	15/06/18
CYH MAR	Marina / Harbour in Medina Estuary			15/06/18
BRL SHR	Black Rock Ledge, Isle of Wight	50.680113	-1.070539	14/06/18
BLF SHR	Bembridge Lifeboat Slip, Isle of Wight	50.689981	-1.071271	13/06/18
BEM HBR	Marina / Harbour near Bembridge, Isle of Wight			14/06/18
SAP SHR	Sandy Point, Chichester Harbour	50.777680	-0.935470	15/07/18
BLP SHR	Black Point, Chichester Harbour	50.787217	-0.938254	16/07/18
SPK MAR	Marina / Harbour in Chichester Harbour			16/07/19
FTC SHR	Fort Cumberland, Langstone Harbour	50.787661	-1.027815	16/07/18
ELS SHR	Eastney Landing Stage, Langstone Harbour	50.795985	-1.029480	17/07/18
SOU MAR	Marina / Harbour in Langstone Harbour			17/07/18
RVC SHR	Royal Victoria Country Park, Southampton Water	50.864264	-1.341894	18/07/18
HAC SHR	Hamble Common Beach, Southampton Water	50.845598	-1.312197	17/07/18
HAP MAR	Marina / Harbour in Hamble Estuary			18/07/18
STP SHR	Stone Pt to Stansore Pt, New Forest	50.785200	-1.347975	20/05/19
INC SHR	Inchmery, New Forest	50.784914	-1.378802	21/05/19
BUK MAR	Marina / Harbour near Beaulieu			21/05/19
MCH SHR	Marchwood, River Test	50.901654	-1.447919	21/05/19
DIB SHR	Dibden Bay, River Test	50.886843	-1.414984	22/05/19
HYT MAR	Marina / Harbour in River Test			22/05/19
CHL SHR	Chilling, Southampton Water	50.817086	-1.244221	19/06/19
HKS SHR	Hook Spit, Southampton Water	50.839732	-1.305623	18/06/19
WAR HBR	Marina / Harbour in Hamble Estuary			19/06/19
NET SHR	Netley, Southampton Water	50.870344	-1.352066	20/06/19
WES SHR	Weston, Southampton Water	50.886856	-1.377542	19/06/19
OCN MAR	Marina / Harbour in Itchen Estuary			20/06/19
OYS SHR	Oysterbeds, Hayling Island	50.831696	-0.979712	01/07/19
NOR SHR	Northney, Hayling Island	50.834996	-0.969628	02/07/19
NOR MAR	Marina / Harbour on Hayling Island			02/07/19
PCH SHR	Portchester, Portsmouth Harbour	50.836990	-1.112791	03/07/19
PAU SHR	Paulsgrove Lake, Portsmouth Harbour	50.844821	-1.103514	04/07/19
PSL MAR	Marina / Harbour in Portsmouth Harbour			03/07/19
SEA SHR	Seaview, Isle of Wight	50.723331	-1.115946	04/07/19
RYD SHR	Ryde Beach, Isle of Wight	50.727933	-1.140563	05/07/19
RYD MAR	Marina / Harbour near Ryde, Isle of Wight			05/07/19

Note: In site code SHR, MAR or HBR = Shore, Marina or Harbour

Appendix II: Alien Species target list

Informal group	Species	Added Yr 2	Sites	Excl.	UK MSFD Lists
Ascidians	*Aplidium cf. glabrum*		B		
	Asterocarpa humilis		B		Y
	Botrylloides violaceus		B		
	Botrylloides diegensis		B		
	Ciona robusta		B		
	Corella eumyota		B		
	Didemnum vexillum		B		Y
	Perophora japonica		B		
	Styela clava		B		Y
Bryozoans	*Bugula neritina*		B		
	Bugulina fulva	Y	B	X	
	Bugulina simplex		B		
	Bugulina stolonifera		B		
	Schizoporella japonica		B		Y
	Tricellaria inopinata		B		
	Watersipora subatra		B		Y
Sponges	*Celtodoryx ciocalyptoides*		B		Y
Anemones	*Diadumene lineata*		B		Y
Molluscs	*Arcuatula senhousia*	Y	B	X	
	Crepidula fornicata		B		Y
	Ensis leei		S	S, I	Y
	Magallana gigas		B		Y
	Mercenaria mercenaria	Y	S	S, I, X	
	Ocinebrellus inornatus		S	S	Y
	Rapana venosa		S	S	Y
	Ruditapes philippinarum		S	S, I	
	Urosalpinx cinerea		S	S	Y

Informal group	Species	Added Yr 2	Sites	Excl.	UK MSFD Lists
Annelid worms	*Ficopomatus enigmaticus*		B		Y
	Hydroides dianthus		B		
	Hydroides elegans		B		
	Hydroides ezoensis		B		
Arthropods	*Ammothea hilgendorfi*		B		
	Amphibalanus amphitrite		B		Y
	Amphibalanus improvisus		B		
	Austrominius modestus		B		
	Caprella mutica		B		Y
	Dyspanopeus sayi		S	S	Y
	Eriocheir sinensis		S	S	Y
	Hemigrapsus sanguineus		S	S	Y
	Hemigrapsus takanoi		S	S	Y
	Hesperibalanus fallax		B		Y
Brown algae	*Colpomenia peregrina*		B		
	Sargassum muticum		B		Y
	Undaria pinnatifida		B		Y
Red algae	*Asparagopsis armata*		S	S	
	Bonnemaisonia hamifera		S	X	Y
	Caulacanthus okamurae		S	S	
	Chrysymenia wrightii		B		
	Gracilaria vermiculophylla		S	S	Y
	Grateloupia turuturu		B		Y
	Melanothamnus harveyi		B	X	
	Pikea californica		B		
	Solieriaceae	Y	S	S, X	
Green algae	*Codium fragile fragile*		B		
	Umbraulva dangeardii	Y	B	X	

Notes:
Added in Yr 2 - Y = Species added to Target List in Year 2 of project.
Sites – Site types where species expected - S = Shore, M = Marina, B = Both
Excl. – Excluded from Marina/Near/Far analyses because: S = Unlikely to occur on pontoons in marinas, I = Infaunal species, X= Inconsistently recorded e.g. added to list in Year 2 (See Sections 2.1.9 and 3.3.5 for further explanation).

Appendix III: Native species target list

Informal group	Species	Added Yr 2	Sites	Excl.
Ascidians	*Ascidia conchilega*		B	
	Ascidia mentula		B	
	Ascidiella aspersa		B	
	Ascidiella scabra		B	
	Botryllus schlosseri		B	
	Ciona intestinalis		B	
	Clavelina lepadiformis		B	
	Dendrodoa grossularia		B	
	Diplosoma listerianum		B	
	Molgula spp.		B	
	Morchellium argus		B	
Bryozoans	*Bugulina flabellata*		B	
	Bugulina turbinata		B	
	Celleporella hyalina		B	
	Conopeum reticulum		B	
	Conopeum seurati		B	
	Crisularia plumosa		B	
	Cryptosula pallasiana		B	
	Einhornia crustulenta		B	
	Electra pilosa		B	
	Oshurkovia littoralis		B	
	Schizoporella unicornis		B	
	Scrupocellaria scruposa		B	
Sponges	*Hymeniacidon perlevis*		B	
	Sycon ciliatum		B	
Anemones	*Actinia equina*		B	
	Metridium senile		B	
	Urticina felina		B	

Informal group	Species	Added Yr 2	Sites	Excl.
Molluscs	*Littorina littorea*		S	S
	Mytilus spp.		B	
	Ocenebra erinaceus		S	S
	Ostrea edulis		B	
Annelid worms	*Arenicola* spp.		S	S
	Hydroides norvegica		B	
	Lanice conchilega		S	S
	Sabella pavonina		B	
	Sabellaria spp.		S	S
	Spirobranchus		B	
	Spirorbinae		B	
Arthropods	*Balanus crenatus*		B	
	Carcinus maenas		B	
	Pisidia longicornis		B	
	Porcellana platycheles		B	
	Semibalanus balanoides		B	
	Verruca stroemia		B	
Brown algae	*Cystoseira* spp.		B	
	Fucus serratus		B	X
	Fucus spiralis		B	X
	Fucus vesiculosus		B	X
	Fucus ceranoides		B	X
	Himanthalia elongata		S	
	Laminaria digitata		B	
	Saccharina latissima		B	
Red algae	*Gracilaria* spp.		S	S
	Halurus spp.		B	
Green algae	*Ulva* spp.		B	
Plants	*Zostera* spp.		S	S

Notes:
Added in Yr 2 - Y = Species added to Target List in Year 2 of project.
Sites – Site types where species expected - S = Shore, M = Marina, B = Both
Excl. – Excluded from Marina/Near/Far analyses because: S = Unlikely to occur on pontoons in marinas, I = Infaunal species, X= Inconsistently recorded e.g. added to list in Year 2 (See Sections 2.1.9 and 3.3.5 for further explanation).

Appendix IV: Descriptions of target AS including current known distribution in Solent

(Table adapted from Wood *et al*., 2015)

Alien species	Description	Level of Threat	Known presence in Solent[1] M=Marina S=Shores	
			Pre-project	This project
Solitary Ascidiacea				
Asterocarpa humilis (Compass sea squirt)	Solitary ascidian native to Southern Hemisphere. First recorded in UK in 2009 in SW England (Bishop *et al.*, 2013).	Recently recognised, and spreading rapidly in England, potential fouler of aquaculture equipment, clumps could clog pipes, potential competitor for food and space with cultured bivalves. Now entering natural habitats.	M	S
Ciona robusta (formerly known as *Ciona intestinalis* Type A)	Solitary ascidian, very similar in appearance to native species *C. intestinalis*. Considered native to the NW Pacific. Currently known only from the SW coast, Newlyn to Torquay (Nydam and Harrison, 2011). For distinguishing features, see Sato *et al.* (2012).	Recently distinguished; threat to biodiversity – 'cryptic' species, potentially hybridises with native *C. intestinalis*, fouler of aquaculture equipment (as is *C. intestinalis*); competes for food with farmed species such as mussels and oysters.		
Corella eumyota (Orange-tipped sea squirt)	Solitary ascidian, widespread throughout cooler waters of southern hemisphere. First recorded in the UK on the S coast in 2004 (Arenas *et al.*, 2006). Now present throughout the UK.	Widespread in UK, forms large clumps, potential fouler of aquaculture equipment; entering natural habitats.	M S	M S
Styela clava (Leathery sea squirt)	Solitary, stalked ascidian native to NW Pacific. First recorded in UK 1953 in Plymouth Sound, Devon (Carlisle, 1954). Widespread in the UK for some decades.	Detrimental to aquaculture in some world regions but may increase biodiversity per unit area of substrate.	MS	MS
Colonial Ascidiacea				
Aplidium cf. glabrum	A colonial ascidian, similar in zooidal morphology to native *Aplidium glabrum*, but found in warmer waters than are typical of the native species (Millar, 1966). Origin and identity unknown.	Widespread in UK, threat to biodiversity and aquaculture through smothering, could block inlet pipes; entering natural habitats.	M	M S
Botrylloides diegensis (San Diego sea squirt)	Colonial ascidian described from the W coast of N America. First recorded in UK in 2004 on the S English coast.	Spreading in England, threat to aquaculture through smothering.	M	MS

Alien species	Description	Level of Threat	Known presence in Solent[1] M=Marina S=Shores	
			Pre-project	This project
Botrylloides violaceus (Orange cloak sea squirt)	Colonial ascidian native to NW Pacific. Grows on hard substrates as well as mussels, solitary ascidians and algae. First recorded in UK 2004 on the SW English coast (Arenas *et al.,* 2006).	Widespread in UK, threat to biodiversity and aquaculture through smothering, could block inlet pipes; entering natural habitats.	M	M S
Didemnum vexillum (Carpet sea squirt)	A colonial ascidian thought to be native to NW Pacific region (Lambert, 2009). First recorded in UK 2008 in Holyhead Marina (Griffith *et al.*, 2009).	Local threat to biodiversity and local aquaculture through smothering. Thought to be a high impact invasive due to its rapid fouling abilities.	M	M S
Perophora japonica (Creeping sea squirt)	A colonial ascidian from of NE Asia, first recorded in Plymouth in 1999 (Nishikawa *et al.*, 2000). Presently occurs in only a limited number of sites in SW and S England, although widespread in France. A record from Milford Haven in 2002, included on various Web sites, was based on a mis-identification.	Local threat currently unknown although the species is starting to appear in natural habitats elsewhere in UK.	M	M S
Bryozoa				
Bugula neritina (Ruby bryozoan)	A purplish-brown bryozoan that forms erect, bushy growths. Present from SW Scotland around Welsh and English coasts to Lowestoft. First recorded in c.1911 but by late 1990s was no longer present, a rapid recolonization has since occurred (Ryland *et al.*, 2011).	Widespread in UK, can affect biodiversity. An abundant fouling organism that colonies a variety of sub-tidal substrata including artificial structures and vessel hulls.	M	M S
Bugulina fulva	Previously called *Bugula fulva.* Yellowish erect bryozoan that forms short compact fan-shaped tufts. Considered cryptogenic in UK, although first described from UK waters in 1960. Distributed around the coast of England and Wales, in artificial habitats, and on shores under boulders, or on kelps.	Effect unknown.	S	MS
Bugulina simplex	Previously called *Bugula simplex.* Erect straw-coloured bryozoan that forms funnel-shaped colonies. Thought to be native to eastern seaboard of N America or the Mediterranean. Until recently there were few UK records (Ryland *et al*., 2011).	Effect unknown.	M	MS

Alien species	Description	Level of Threat	Known presence in Solent[1] M=Marina S=Shores	
			Pre-project	**This project**
Bugulina stolonifera	Previously called *Bugula stolonifera.* Greyish-buff erect bryozoan that forms short compact tufts. Native to the Atlantic and Mediterranean. Until recently only known from S Wales and a few isolated English sites (Ryland *et al*., 2011).	Effect unknown.	M	MS
Schizoporella japonica (Orange ripple bryozoan)	A bright orange encrusting bryozoan native to the N Pacific. Recorded in Holyhead marina in 2010, only other UK records are from Scotland and Plymouth (Ryland *et al.*, 2014; Loxton *et al*., 2016).	Recently recognised as an IAS. Can form encrustations on ships, piers, buoys & other man-made structures in harbours and marinas. May compete for space with native spp. and *S. japonica* is known to inhibit the growth of adjacent species.		
Tricellaria inopinata (Tufty-buff bryozoan)	An erect bryozoan native to temperate Pacific. Capable of enduring a wide spectrum of temperatures and salinities, as well as high organic content. Settles on a wide range of anthropogenic and natural substrata. First recorded in UK 1998 on S English coast (Dyrynda *et al*., 2000).	Widespread in UK. Fouling nuisance and can affect biodiversity; entering natural habitats.	MS	MS
Watersipora subatra (Red ripple bryozoan)	Previously referred to as *Watersipora subtorquata*. An orange/red encrusting bryozoan from the S Hemisphere. Occurring from the lower intertidal to shallow sub-tidal. First recorded in Plymouth in 2008 (Ryland *et al*., 2009), it is now known from Plymouth to Poole Harbour, and in France from Brittany and Bordeaux.	Tolerant to copper based antifoulants. Spreading rapidly in England. It is highly invasive and has become common on coastlines throughout global cool-temperate waters since the 1980s.	M	MS
Porifera				
Celtodoryx ciocalyptoides (Cauliflower sponge)	Sponge native to NW Pacific. Present in N Sea, the Oosterschelde and Le Havre, and the Gulf of Morbihan.	Grows in large extensive patches smothering. Grows on *Eunicella verrucosa* Pink sea fan.	No UK records	No UK records
Cnidaria				
Diadumene lineata (Orange-striped anemone)	Small orange-striped anemone, native to Pacific. Probably introduced from Japan into the Atlantic towards the end of the 19th century. Distributed around Britain and throughout	Effect unknown.	M	MS

Alien species	Description	Level of Threat	Known presence in Solent[1] M=Marina S=Shores	
			Pre-project	This project
	continental Europe (Stephenson, 1935; Williams, 1975).			
Arthropoda				
Ammothea hilgendorfi (Japanese sea spider)	Pycnogonid native to N Pacific. Thought to be introduced as hull fouling from Japan. First recorded in the UK in Southampton Water in 1978 (Bamber, 1985; Bamber, 2012).	Preys on hydroids and anemones.	MS	MS
Amphibalanus amphitrite (Striped barnacle)	Species of acorn barnacle native to SW Pacific and Indian Oceans. First recorded in UK in 1937 in Shoreham Harbour, Sussex (Bishop, 1950). Populations have been found in S England and S Wales.	Now occurring on S coast of England. Can be a fouling nuisance on yacht hulls and equipment.	M	MS
Amphibalanus improvisus (Bay barnacle)	Smooth, white or pale grey, 6-plated barnacle with a cosmopolitan distribution. First recorded in the UK by Darwin in 1854. Tolerant of brackish waters.	May dominate and outcompete native species, especially for available habitat. It can be a nuisance through fouling of ships' hulls, water inlet pipes, aquaculture products and equipment and other submerged structures.	M	MS
Austrominius modestus (Darwin's barnacle)	Four-plated barnacle native to Australasia, first recorded in UK in 1946 (Crisp, 1958).	Widespread throughout UK, competes for space with native barnacles. Has largely displaced other barnacles in estuaries in SW Britain although impacts less significant on exposed rocky shores.	MS	MS
Caprella mutica (Japanese skeleton shrimp)	Amphipod native to NE Asia. First recorded in the UK in 2000 from a salmon farm in Oban, Scotland (Willis *et al.*, 2004).	Widespread, serious threat to native skeleton shrimp populations even at low densities. On the west coast of Scotland, their abundance can reach 300,000 individuals m -2. It has the potential for significant impacts on benthic communities.	M	MS
Dyspanopeus sayi (Say's mud crab)	Crab. Native to Atlantic coast of N America. First recorded in UK in 1960 in Swansea area. No current records.	Preys on bivalves such as oysters and mussels, other crabs and even lobsters. Also barnacles and gastropods. Highly invasive in Black sea.		
Eriocheir sinensis (Chinese mitten crab)	Crab native to Asia. Inhabits rivers, migrating to estuary mouths to breed. First introduced to the Thames Estuary in 1935, now established in several sites throughout England & Wales.	Damage to riverbanks and increase to river turbidity and gravel siltation (can affect fish spawning). Consume fish eggs and invertebrates. Damage to eel fishing nets.		

Alien species	Description	Level of Threat	Known presence in Solent[1] M=Marina S=Shores	
			Pre-project	This project
Hemigrapsus takanoi (Brush-clawed crab) and *H. sanguineus* (Asian shore crab)	Small crabs native to the NW Pacific, differentiated by teeth on the carapace that are more acute in *H. sanguineus*). Occurs on muddy and rocky shores and in sheltered estuaries and port area. First UK records of *H. takanoi* from R. Medway and Brightlingsea in 2014 (Wood *et al.*, 2015). First records of *H. sanguineus* from mainland GB (outside Channel Islands) from Wales and Kent in 2014 (Seeley *et al.*, 2015).	Threat to biodiversity as it competes with native shore crab *Carcinus maenas.* Threats to mussel and oyster populations have also been noted outside UK.		
Hesperibalanus fallax	Previously called *Solidobalanus fallax. S*mall 6-plated barnacle with calcareous base, typically epibiotic. Plates white with reddish-purple patches. Native to tropical Atlantic coast of Africa. Rare along SW coasts of England and Wales but becoming more frequent. First UK record 1994 (Southward *et al*., 2004).	Fouling of economically important species e.g. scallops and spider crabs. Also fouls artificial substrates e.g. lobster pots, floating plastics.		
Mollusca				
Arcuatula senhousia (Asian date mussel)	Small mytilid mollusc, very recently arrived in UK, first recorded in 2016 in the Solent area (NBN Atlas; Barfield *et al*., 2018). Native to the NW Pacific. Found in intertidal and shallow sub-tidal habitats.	Can form continuous high-density mats that can then have negative impacts on biodiversity. May interact with *Zostera* (Barfield *et al*., 2018).	S	M (dead)
Crepidula fornicata (Slipper limpet)	Medium sized gastropod native to E coast of the Americas from Canada and Mexico. British population was introduced in 1890 in association with imported oysters (Eno *et al.*, 1998).	Habitat alteration, threat to biodiversity and aquaculture. Now a pest in commercial oyster beds.	MS	MS
Ensis leei (American jackknife cla*m)*	A thin elongated bivalve mollusc native to NE coast of USA, likely introduced to Europe from larvae present in ballast water, although the precise method of introduction to UK is unknown. First recorded in UK on Holme Beach, Norfolk (Howlett, 1990).	Currently no direct impacts to native species have been reported.		

Alien species	Description	Level of Threat	Known presence in Solent[1] M=Marina S=Shores	
			Pre-project	**This project**
Magallana gigas (Pacific oyster)	Previously called *Crassostrea gigas*. A bivalve mollusc with thick, rough shells. Occurs naturally in Japan and SE Asia. First introduced from Portugal into the River Blackwater, Essex, in 1926 (Utting and Spencer, 1992).	Displacement of native oysters; reef formation leading to habitat alteration.	MS	MS
Mercenaria mercenaria American hard-shelled clam)	A large bivalve mollusc, native to NE USA. Introduced to UK record for aquaculture 1864, first wild populations 1960. Currently distributed in eastern Southampton waters, as well as Portsmouth and Langstone harbours, in some locations along the north coast of the Isle of Wight, and the Blackwater estuary in Essex. Has also been found in Loch Sunart, Scotland.	Unknown.	S	S
Ocinebrellus inornatus (Japanese oyster drill)	Predatory gastropod, previously called *Ocenebra inornata*. Originally from the NW Pacific, including Japan. First introduced to the USA in the 1920s likely with imports of Pacific oysters (*Magallana gigas*). First European records were from SW France in 1995.	Predator of bivalves. Serious threat to oysters.	No UK records	No UK records
Rapana venosa (Veined rapa whelk)	Large predatory gastropod. Native to NW Pacific. Not considered established in UK, although a few isolated records. Present in N Sea, France & Netherlands.	Consumes range of ecologically and commercially important invertebrates. Out-competes native common whelk. Serious impact in Black Sea.	Not established in UK	Not established in UK
Ruditapes philippinarum (Manila clam)	A bivalve mollusc with a thick, oval shell, usually cream or grey with green or brown markings. Native to NW Pacific. It was introduced to Poole Harbour for aquaculture in the 1980s and has since become established and spread to the Solent.	Linked to declines in other filter feeding bivalves by introducing disease and competing for resources with other species.	S	S
Urosalpinx cinerea (American oyster drill)	A gastropod native to E coast USA, likely introduced to UK with American oysters. First recorded in Essex oyster grounds in 1927 (Orton and Winckworth, 1928). Now widely distributed across Essex and Kent coasts.	Major pest to the commercial shellfish industry preying heavily on native and introduced oyster species, and mussels. Feeds preferentially on oyster spat and has been reported to decimate stocks in some estuaries. Also feeds on barnacle spat.		

Alien species	Description	Level of Threat	Known presence in Solent[1] M=Marina S=Shores	
			Pre-project	This project
Polychaeta				
Ficopomatus enigmaticus (Trumpet tube worm)	A tube worm of unknown origin. Occurs in warm and temperate regions of both S and N hemispheres. Originally observed in London Docks in 1922 (Monro, 1924), it favours coastal brackish waters.	Aggregations can change the geomorphology of the local ecosystem by altering hydrodynamic and sediment characteristics and provide complex habitat for benthic species. May enhance water quality by removing particulate matter, but also increase eutrophication reported. The tubes can be a fouling nuisance and block pipes.	MS	MS
Hydroides dianthus	A serpulid tube worm, native to the NE USA. First UK record from Hamble Spit in 1970 (Zibrowius, 1978; Thorp *et al*., 1987)	Unknown.	MS	MS
Hydroides elegans	A serpulid tube worm native to Australasia. First UK record 1937 (Zibrowius & Thorp, 1989). Very few UK records, only Solent records from 1993, 1994, and 2016 (single specimen).	Unknown.	M	
Hydroides ezoensis	A tube worm thought to originate from Japan, indigenous to NW Pacific. First recorded in UK from Southampton Water in 1976 (Thorp *et al.*, 1987).	Aggregations can be a nuisance, fouling harbour structures and ships' hulls. May provide habitat for free-living and sessile invertebrates.	MS	MS
Algae				
Asparagopsis armata (Harpoon weed)	Delicate red seaweed with barbed branches, often pinkish in colour. Native to Pacific and Indian Oceans, this species was first recorded in UK in 1949 at Lundy (Skewes, 2003).	Effects unknown.	S	
Bonnemaisonia hamifera (Hook weed)	Delicate red seaweed readily identifiable by the presence of curved hooks. Native to Japan and first recorded in UK in 1890s with records from Cornwall, Dorset and Isle of Wight (Bunker *S*,, 2012).	Effects unknown.	S	
Caulacanthus okamurae (Pom-pom weed)	Small red seaweed that forms springy clumps of tangled 'pom-poms' attached by many scattered holdfast pads. Native to NW Pacific and first recorded in UK between 2000 and 2005 along south coast (Brodie *et al.*, 2015)	Forms dense turfs that can alter the habitat leading to displacement of macro invertebrates, such as barnacles.		

Alien species	Description	Level of Threat	Known presence in Solent[1] M=Marina S=Shores	
			Pre-project	This project
Chrysymenia wrightii Golden membrane weed)	Large, glistening red seaweed. Indigenous to Japan. First UK record from Falmouth in 2013 (Bunker, 2014).	Effects unknown.		
Codium fragile fragile (Green sea fingers)	Green seaweed with spongy finger-like branches. Native to the Pacific Ocean: Japan and Korea. In the UK it was first recorded from the Yealm Estuary, Devon in 1939, growing on oyster shells (Silva, 1955).	Has the potential to compete with native species for space, forming dense assemblages and potentially altering community structure. A nuisance to fisheries and aquaculture, particularly on NW Atlantic shores, it fouls nets and may attach to uplift and move commercially produced shellfish and seaweed.	MS	S
Colpomenia peregrina (Oyster thief)	Brown seaweed forming inflated thin-walled hollow spheres. Native to the Pacific Ocean. Introduced to Cornwall and Dorset from France in 1907 (Cotton, 1908).	May smother native species; can attach to oysters, become air-filled and buoyant then float away with the animal.	MS	MS
Gracilaria vermiculophylla (Worm wart weed)	Red seaweed with long thin fronds. Native to NW Pacific, large populations now exist in Dorset (Maggs *et al.*, 2014)	Forms algal mats. Large populations may displace native species and cause mortality in larval stages by reducing light and oxygen availability.		
Grateloupia turuturu (Devil's tongue weed)	Large red seaweed found growing on hard substrates down to 2 m below low water mark. Native to Pacific, probably Japan. Probably introduced to UK by spores travelling in ballast water. First recorded at Southsea beach in the Solent, in 1969 (Farnham and Irvine, 1973).	Whilst no ecosystem impacts are yet to be recorded in UK, elsewhere *G. turuturu* has been shown to be a threat to native red algae (e.g. *Chondrus crispus* in North America) where the large, broad blades may shade neighbouring species. Increasing sea temperatures likely to increase presence.	MS	MS
Melanothamnus harveyi Harvey's siphon weed)	Previously known as *Polysiphonia harveyi* and *Neosiphonia harveyi*. Very fine red alga native to Pacific, probably Japan. First UK record Weymouth 1908 (McIvor *et al*., 2001). South and east coast of England to Essex, Wales and W and N coasts of Scotland (Bunker, 2017).	Effects unknown.	MS	S
Pikea californica (Captain Pike's weed)	A dense bushy red seaweed. Native to Pacific coast of N. America. Earliest UK record 1967 from Isles of Scilly (Maggs & Ward, 1996). First mainland record 2015 from Cornish marina.	Effects unknown.		

Alien species	Description	Level of Threat	Known presence in Solent[1] M=Marina S=Shores	
			Pre-project	This project
Sargassum muticum (Wireweed)	Large brown seaweed native to Japan and NW Pacific. Grows on hard substrates in shallow water down to approx. 5 m. First recorded in UK 1971 in Bembridge on Isle of Wight (Farnham *et al.*, 1973).	Overtops and shades native seaweeds with dense stands being shown to also increase sedimentation and alter temperatures in rockpools. In Solent primarily in areas where seagrass present.	MS	MS
Solieriaceae	Branched, juicy red seaweed, native to the Pacific or E coast of USA. Likely to be either *Agardhiella subulata* or *Sarcodiotheca gaudichaudi* (awaiting DNA). First recorded in UK in Solent area on shores in 1973 (Farnham & Irvine, 1979; Farnham, 1980), believed to be still restricted to the Solent.	Unknown.	S	S
Umbraulva dangeardii	Previously called *Ulva olivascens* and *Umbraulva olivascens.* Large green Ulva-like seaweed, presumed native to Pacific Ocean (Maggs *et al*., 2007). First UK record 1993. Known from sites in S England, Wales and Ireland. Sometimes abundant in wave-sheltered conditions such as harbours and sheltered bays.	Unknown		M
Undaria pinnatifida (Wakame)	Large brown seaweed native to temperate regions of NW Pacific. Grows on hard substrates from low intertidal to approx. 18 m. First recorded in UK in 1994 on floating pontoons in the Solent where it is suspected to have been introduced from Brittany (Fletcher and Manfredi, 1995).	Competes for space with native kelp species. May be a nuisance fouling jetties, vessels, moorings and buoys.	MS	MS

Notes:
[1] Prior presence in marinas/harbours sourced from MBA Bishop Group surveys 2004 – 2017 and NBN Atlas.
Prior presence on shores sourced from NBN Atlas on 20/12/2019, and cited literature.

Appendix IV (ii) Related References

Arenas, F.F., Bishop, J.D.D., Carlton, J.T., Dyrynda, P.J., Farnham, W.F., Gonzalez, D.J., Jacobs, M.W., Lambert, C., Lambert, G., Nielsen, S.E., Pederson, J.A., Porter, J.S., Ward, S. & Wood, C.A. 2006. Alien species and other notable records from a rapid assessment survey of marinas on the south coast of England. *Journal of the Marine Biological Association of the United Kingdom*, 86: 1329–1337.

Bamber, R.N. 1985. The itinerant sea spider *Ammothea hilgendorfi* (Böhm) in British waters. Proceedings of Hampshire Field Club & Archaeological Society, 41: 269-270.

Bamber, R.N. 2012. Anthropogenic spread of the immigrant sea-spider *Ammothea hilgendorfi* (Arthropoda: Pycnogonida: Ammotheidae) in UK waters. *Marine Biodiversity Records*, 5: e78 doi: https://doi.org/10.1017/S1755267212000668.

Barfield, P., Holmes, A., Watson, G. and Rowe, G. 2018. First evidence of *Arcuatula senhousia* (Benson, 1842), the Asian Date Mussel, in UK waters. *Journal of Conchology*, 43(2), pp.217-222.

Bishop, M.W.H. 1950. Distribution of *Balanus amphitrite* Darwin var. denticulata (Broch). *Nature*, 165: 409.

Bishop, J.D.D., Roby, C., Yunnie, A.L.E., Wood, C.A., Lévêque, L., Turon, X. & Viard, F. 2013. The Southern Hemisphere ascidian *Asterocarpa humilis* is unrecognised but widely established in NW France and Great Britain. *Biological Invasions*, 15: 253-260, doi: https://doi.org/10.1007/s10530-012-0286-x.

Brodie, J., Wilbraham, J., Pottas, J. and Guiry, M.D. 2015. A revised check-list of the seaweeds of Britain. *Journal of the Marine Biological Association of the United Kingdom*, .1-25.

Bunker, F. StP. D., Maggs, C.A., Brodie, J.A., and Bunker, A.R. 2017. Seaweeds of Britain and Ireland. Second Edition. Wild Nature Press, Plymouth, UK.

Bunker, F. 2014. *Chrysymenia wrightii* (Wrights golden membrane weed) a new non-native to southwest England. *The Phycologist*, 87, 20.

Carlisle, D.B. 1954. *Styela mammiculata* n.sp., a new species of ascidian from the Plymouth area. *Journal of the Marine Biological Association of the United Kingdom*, 33: 329-334.

Cotton, A.D. 1908. *Colpomenia sinuosa* in Britain. *Journal of Botany*, 46: 82-83.

Crisp, D.J. 1958. The spread of *Elminius modestus* Darwin in north-west Europe. *Journal of the Marine Biological Association of the United Kingdom*, 37: 483-520.

Dyrynda, P.E.J., Fairall, V.R., Occhipinti Ambrogi, A. & d'Hondt, J.L. 2000. The distribution, origin and taxonomy of *Tricellaria inopinata* d'Hondt and Occhipinti Ambrogi, 1985, an invasive bryozoan new to the Atlantic. Journal of Natural History, 34:1993-2006.

Eno, C.N. 1998. The introduction to British waters of non-native marine molluscs and the implications to nature conservation interests. *Journal of Conchology*, 287–294.

Farnham, W., Fletcher, R. & Irvine, L.M. 1973. Attached *Sargassum* found in Britain. *Nature,* 243: 231-232.

Farnham, W.F. & Irvine, L.M. 1973. The addition of a foliose species of *Grateloupia* in the British marine flora. *British Phycological Journal*, 8: 208-209.

Farnham, W.F., & Irvine, L.M. 1979. Discovery of members of the red algal family *Solieriaceae* in the British Isles. *British Phycological Journal*, 14: 123.

Farnham, W.F. 1980. Studies on aliens in the marine flora of southern England. In: *The Shore Environment Vol. 2: Ecosystems*. (Price, J.H., Irvine, D.E.G. & Farnham, W.F. Eds), pp. 875-914. London: Academic Press.

Fletcher, R. & Manfredi, C. 1995. The occurrence of *Undaria pinnatifida* (Phaeophyceae, Laminariales) on the south coast of England. *Botanica Marina*, 38: 355–358.

Griffith, K., Mowat, S., Holt, R.H.F., Ramsay, K., Bishop, J.D.D., Lambert, G. & Jenkins, S.R. 2009. First records in Great Britain of the invasive colonial ascidian *Didemnum vexillum* Kott, 2002. *Aquatic Invasions*, 4: 581–590.

Howlett, D. J. 1990. The arrival in Britain of *Ensis americanus*. Conchologist's Newsletter, 114: 301–302.

Lambert, G. 2009. Adventures of a sea squirt sleuth: unravelling the identity of *Didemnum vexillum*, a global ascidian invader. *Aquatic Invasions*, 4: 5-28.

Loxton, J., Wood, C. A., Bishop, J. D. D., Porter, J. S., Jones, M. S., & Nall, C. R. 2017 Distribution of the invasive bryozoan *Schizoporella japonica* in Great Britain and Ireland and a review of its European distribution. *Biological Invasions*, 1-11.

Maggs C.A. and Kelly J. 2007. In Brodie J., Maggs C.A. and John D.M. (eds.) Green seaweeds of Britain and Ireland. London: British Phycological Society, pp. 189–201.

Maggs, C. A. & Magill C.L. 2014. GB Non-native Organism Rapid Risk Assessment for *Gracilaria vermiculophylla*. www.nonnativespecies.org

McIvor L., Maggs C.A., Provan J. and Stanhope M.J. 2001 rbcL sequences reveal multiple cryptic introductions of the Japanese red alga *Polysiphonia harveyi*. *Molecular Ecology* 10, 911–919.

Millar, R.H. 1966. Tunicata, Ascidiacea. Marine Invertebrates of Scandinavia, 1: 1-123. Monro,

C.C.A. 1924. A serpulid polychaete from London docks (*Mercierella enigmatica* Fauvel). Annals and Magazine of Natural History, 13: 155-159.

Nishikawa, T., Bishop, J.D.D. & Sommerfeldt, A.D. 2000. Occurrence of the alien ascidian *Perophora japonica* at Plymouth. *Journal of the Marine Biological Association of the United Kingdom*, 80: 955-956.

Nydam, M.L., Harrison, R.G. 2011. Introgression despite substantial divergence in a broadcast spawning marine invertebrate. *Evolution*, 65: 429-442.

Orton, J. & Winckworth, R. 1928. The occurrence of the American oyster pest *Urosalpinx cinerea* (Say) on English oyster beds. *Nature*, 122: 241–241.

Ryland, J. S. .1960. The British species of *Bugula* (Polyzoa). *Proceedings of the Zoological Society of London* 134: 65-105

Ryland, J.S., De Blauwe, H., Lord, R. & Mackie, J.A. 2009. Recent discoveries of alien *Watersipora* (Bryozoa) in Western Europe, with redescriptions of species. *Zootaxa*, 2093: 43-59.

Ryland, J.S., Bishop, J.D.D., De Blauwe, H., El Nagar, A., Minchin, D., Wood, C.A. & Yunnie, A.L.E. 2011. Alien species of *Bugula* (Bryozoa) along the Atlantic coasts of Europe. *Aquatic Invasions*, 6: 17-31.

Ryland, J.S., Holt, R., Loxton, J., Spencer Jones, M.E. & Porter, J.S. 2014. First occurrence of the non-native bryozoan *Schizoporella japonica* Ortmann (1890) in Western Europe. *Zootaxa*, 3780: 481-502.

Sato, A., Satoh, N. & Bishop, J.D.D. 2012. Field identification of 'types' A and B of the ascidian *Ciona intestinalis* in a region of sympatry. Marine Biology, 159: 1611-1619

Seeley, B., Sewell, J. & Clark, P.F. 2015. First GB records of the invasive Asian shore crab, *Hemigrapsus sanguineus* from Glamorgan, Wales and Kent, England. *Marine Biodiversity Records*, 8 (102).

Stephenson, T.A. 1935. The British sea anemones, Vol. 2. London, The Ray Society.

Silva, P.C. 1955. The dichotomous species of *Codium* in Britain. *Journal of the Marine Biological Association of the United Kingdom*, 34: 565-577.

Skewes, M. 2003. *Asparagopsis armata* Harpoon weed. In Tyler-Walters H. and Hiscock K. (eds) Marine Life Information Network: Biology and Sensitivity Key Information Reviews, [on-line]. Plymouth: Marine Biological Association of the United Kingdom. [cited 25-02-2019]. Available from: https://www.marlin.ac.uk/species/detail/1619

Thorp, C.H., Pyne, S. & West, S.A. 1987. *Hydroides ezoensis* Okuda, a fouling serpulid new to British coastal waters. *Journal of Natural History*, 21: 863-877.

Utting, S. & Spencer, B. 1992. Introductions of marine bivalve molluscs into the United Kingdom for commercial culture–case histories. In: ICES marine science symposia. Copenhagen [ICES MAR. SCI. SYMP.]. 1992.

Williams, R. 1975. Catch-tentacles in sea anemones: occurrence in *Haliplanella luciae* (Verrill) and a review of current knowledge. *Journal of Natural History*, 9: 241–248.

Willis, K., Cook, E., Lozano-Fernandez, M. & Takeuchi, I. 2004. First record of the alien caprellid amphipod, *Caprella mutica*, for the UK. *Journal of the Marine Biological Association of the United Kingdom*, 84: 1027–1028.

Wood, C.A., Bishop, J.D.D, Davies, C.J., Delduca, E.L., Hatton, J.C., Herbert, R.J.H. & Clark, P.F. 2015. *Hemigrapsus takanoi* Asakura and Watanabe, 2005 (Crustacea: Decapoda: Brachyura: Grapsoidea): first records of the brush-clawed shore crab from Great Britain. *Bioinvasions Records*, 4(2): 109 – 113.

Zibrowius, H. 1978. Introduction du polychète Serpulidae japonais *Hydroides ezonesis* sur la côte atlantique française et remarques sur la répartition d'autres espèces de Serpulidae. *Tethys*, 8, pp.141-150.

Zibrowius, H., & Thorp, C. H. 1989. A review of the alien serpulid and spirorbid polychaetes in the British Isles. *Cahiers de Biologie Marine*, *30*, 271-285.

Appendix V: Marina Survey Recording Form

Marina		Duration
Date		
Observer		
Start time:		
End time:		

	SUBSTRATES
Pon-toon(s) visited	
Float material	
Ropes	
Buoys	
Tyres	
Kelps	

First seen: quarter hr **1**, **2**, **3**, or **4**
Abundance:
1 (R/O) **2** (F/C) **3** (A/S)

	Non-native Species	1st qtr	Abund	+Tidal
Squirts	*Asterocarpa humilis*			
	Ciona robusta			
	Corella eumyota			
	Styela clava			
Col. squirts	*Aplidium cf. glabrum*			
	Botrylloides diegensis			
	Botrylloides violaceus			
	Botryllids indet to check			
	Didemnum vexillum			
	Perophora japonica			
Bryozoa	*Bugula neritina*			
	Bugulina to check			
	Schizoporella japonica			
	Tricellaria inopinata			
	Watersipora subatra			
Cnid	*Diadumene lineata*			
	Tubularia / Ecto to check			
Moll	*Crepidula fornicata*			
	Magallana gigas			
Tube	*Ficopomatus enigmaticus*			
	Hydroides sp. to check			
Arthrop	*Ammothea hilgendorfi*			
	(Amphi-)Balanus to check			
	Austrominius modestus			
	Caprella mutica			
Algae	*Codium fragile fragile*			
	Colpomenia peregrina			
	Grateloupia turuturu			
	Sargassum muticum			
	Umbraulva olivascens			
	Undaria pinnatifida			

	Native Species	1st qtr	Abund	+Tidal
Squirts	*Ascidia conchilega*			
	Ascidiella aspersa			
	Ascidiella scabra			
	Ciona intestinalis			
	Molgula sp.			
Col. squirts	*Botrylloides leachii*			
	Botryllus schlosseri			
	Clavelina lepadiformis			
	Diplosoma listerianum			
	Morchellium argus			
Bryozoa	*Celleporella hyalina*			
	Conopeum sp.			
	Cryptosula pallasiana			
	Electra pilosa			
Spon	*Hymeniacidon perleve*			
	Sycon ciliatum			
Cni	*Metridium senile*			
Moll	*Mytilus* sp.			
	Ostrea edulis			
Tubew	*Sabella pavonina*			
	Spirobranchus sp.			
	Spirorbid sp.			
Arthro	*Carcinus maenas*			
	Pisidia longicornis			
	Verruca stroemia			
Algae	*Fucus* sp.			
	Laminaria digitata			
	Saccorhiza polyschides			
	Saccharina latissima			
	Ulva sp.			

Appendix VI: Shore Environmental Recording Form

Natural England (EMFF) Solent Survey

Location	Date	Surveyors
		Taylor / Wood / Bishop

Nearest tidal station	Predicted low tide time	Predicted low tide height

Cloud cover %	Precipitation	Wind Beaufort No	Wind direction	Sea state WMO Characteristics	Sea state WMO Code

Photos (enter photographer's initials)			
Whole site	Section 1	Section 2	Section 3

Site map sections annotated 1,2,3 & initials

Landscape	Littoral width	Littoral aspect

Risk assessment	Additional risks of present location/conditions	Response
(see general shore survey RA)		

Habitat description form completed	Site designations

Pressure	Air temp.	Sea temp.	Lat/Long SW corner	Lat/long NE corner

Appendix VII: Shore Survey Recording Form

Name:	Date:	Site:

NON-NATIVES (Red = COLLECT to check)

Group	Species	Low shore (60 min)	1/4 hr found	Image / Spec.	Abundance	Mid / High shore	Image / Spec.	Abundance
Sea squirts	*Aplidium* cf. *glabrum*							
	Asterocarpa humilis							
	Botrylloides diegensis							
	Botrylloides violaceus (l'vae?)							
	Corella eumyota							
	Didemnum vexillum							
	Perophora japonica							
	Styela clava							
Bryozoans	*Bugula neritina*							
	Schizoporella japonica							
	Tricellaria-Bugulina							
	Watersipora subatra							
Cn	*Diadumene lineata*							
Molluscs	*Arcuatula senhousia*							
	Crepidula fornicata							
	Ensis sp.							
	Magallana gigas							
	Ruditapes sp.							
	Urosalpinx / Ocenebra							
Tubes	*Ficopomatus enigmaticus*							
	Hydroides sp.							
Arthropods	*Ammothea hilgendorfi*							
	(Amphi-) Balanus sp.							
	Austrominius modestus							
	Caprella mutica							
	Hemigrapsus sp.							
Algae	*Asparagopsis armata*							
	Bonnemaisonia hamifera							
	Codium fragile fragile							
	Colpomenia peregrina							
	Gracilaria sp.							
	Grateloupia turuturu							
	Sargassum muticum							
	Solieriaceae sp.							
	Undaria pinnatifida							
	Other NIS							

1/4 hr found: 1st, 2nd, 3rd, 4th. Abundance 0, 1, 2, 3.

Substrates colonised by each species

Rock = **R**
Under boulder/cobble = **U**
Top of boulder/cobble = **T**
Pebble = **P**
Gravel/sand = **G**
Mud/sand = **M**
Shell = **S**
Artificial substrate = **X**

Overhang = **O**
Crevice = **C**
Water retained intertidally (eg in pool) = **W**
Red alga = **A**
Fucoid = **F**
Kelp blade = **K**
Kelp holdfast = **H**
Sargassum = **J**

Dead specimen = **(D)**

Dominant substrate circled ○

Combine with '+', e.g. fucoid under water = **F+W**.

NATIVES

Group	Species	Low shore (60 min)	1/4 hr found	Image / Spec.	Abundance	Mid / High shore	Image / Spec.	Abundance
Squirts	*Ascidiella* sp.							
	Botryllus schlosseri							
	Dendrodoa grossularia							
	Molgula sp.							
	Morchellium argus							
Bryozoa	Crisiid sp.							
	Cryptosula pallasiana							
	Oshurkovia littoralis							
	Schizoporella unicornis							
	Hymeniacidon perleve							
Anems	*Actinia equina*							
	Urticina felina							
Molluscs	*Littorina littorea*							
	Mytilus sp.							
	Ostrea edulis							
Tubeworms	*Lanice conchilega*							
	Sabella pavonina							
	Sabellaria sp.							
	Spirobranchus sp.							
Arthropods	*Carcinus maenas*							
	Pisidia longicornis							
	Porcellana platycheles							
	Semibalanus balanoides							
	Verruca stroemia							
Algae	*Cystoseira* sp.							
	Fucus serratus							
	Fucus vesiculosus							
	Halurus sp.							
	Himanthalia elongata							
	Laminaria digitata							
	Saccharina latissima							
	Ulva sp.							
	Zostera sp.							

	Low		Mid/high
Start of section:	Photo shows:	Time:	Time:
End of section:	Photo shows:	Time:	Time:

Substrates examined (tally)	Low	Mid/High
Boulders turned		
Tidepools visited		
Artificial substrates		
Kelp holdfasts		

Appendix VIII (i): Summary Marina Survey Form (front)

Survey title **Solent EMFF 2019**

MARINA: **DATE:** **OBSERVERS:** WOOD/ BISHOP/TAYLOR

1-hour search ?		S‰	T°C	Secchi depth m	Pots used:
Start time:	Surf.				Vials used:
Stop time:	2m				

NON-NATIVES	Score as Unitary or Colonial ↓	Ab'd ce	Field comments ← 0, 1, 2, 3	Preserved: Pot	Preserved: Vial	Preserved: ID comments (incl. Y/N)
Asterocarpa humilis	U					
Ciona robusta	U					
Corella eumyota	U					
Styela clava	U					
Aplidium cf. *glabrum*	C					
Botrylloides diegensis	C					
Botrylloides violaceus	C					
Botryllids indet.	C		LARVAE?			
Didemnum vexillum	C					
Perophora japonica	C					
Bugula neritina	C					
Bugulina sp.	C					
Schizoporella japonica	C					
Tricellaria inopinata	C					
Watersipora subatra	C					
Celtodoryx ciocalyptoides	C					
Diadumene lineata	U					
Tubularia & *Ectopleura* sp.	'C'					
Crepidula fornicata	U					
Magallana gigas	U		TIDAL:			
Ficopomatus enigmaticus	C					
Hydroides sp.	U					
Ammothea hilgendorfi	U					
(Amphi-)Balanus sp.	U		TIDAL:			
Austrominius modestus	'C'		TIDAL:			
Caprella mutica	U		:			
Hesperibalanus fallax	U					
Bonnemaisonia hamifera						
Caulacanthus okamurae	U					
Chrysymenia wrightii	U					
Codium fragile fragile	U					
Colpomenia peregrina	U					
Grateloupia turuturu	U					
Pikea californica	U					
Sargassum muticum	U					
Umbraulva olivascens	U					
Undaria pinnatifida	U					

Appendix VIII (ii): Summary Marina Survey Form (back)

NATIVES	Score as Unitary or Colonial ↓	Ab'd ce	Field comments	Preserved		
			← 0, 1, 2, 3	Pot	Vial	ID comments (incl. Y/N)
Ascidia conchilega	U					
Ascidia mentula	U					
Ascidiella aspersa	U					
Ascidiella scabra	U					
Ciona intestinalis	U					
Dendrodoa grossularia	U					
Molgula sp.	U					
Botrylloides leachii	C					
Botryllus schlosseri	C					
Clavelina lepadiformis	C					
Diplosoma listerianum	C					
Lissoclinum perforatum	C					
Morchellium argus	C					
Trididemnum sp.	C					
Alcyonidium sp.						
Celleporella hyalina	C					
Conopeum sp.	C					
Cryptosula pallasiana	C					
Ctenostome 'turf'	C					
Electra pilosa	C					
Membranipora membr'acea	C					
Hymeniacidon perleve	C					
Sycon ciliatum	U					
Metridium senile	U					
Unidentified anemones	U		NO. of DIFF TYPES:			
Mytilus sp.	U					
Ostrea edulis	U		TIDAL:			
Sabella pavonina	U					
Serpulid worms (other)	U					
Spirobranchus sp.	U					
Spirorbid sp.	C					
Carcinus maenas	U					
Pisidia longicornis	U					
Verruca stroemia	U		TIDAL:			
Fucus sp.	U					
Laminaria digitata	U					
Saccharina latissima	U					
Saccorhiza polyschides	U					
Ulva sp.	U					

Appendix IX (i): Summary Shore Survey Form (front)

Survey title **Solent EMFF 2019**

LOCALITY: **DATE:** **OBSERVERS:** WOOD/ BISHOP/TAYLOR

Lower shore (1 h)	Middle-upper shore	Pots used
Start time:	Start time:	Vials used
End time:	End time:	

NON-NATIVES	Score as **U**nitary or **C**olonial ↓	**Ab'd ce**	Field comments ← **0, 1, 2, 3**	Preserved: Pot	Vial	ID comments (incl. Y/N)
Aplidium cf. *glabrum*	C					
Asterocarpa humilis	U					
Botrylloides diegensis	C					
Botrylloides violaceus	C		LARVAE?			
Botryllidae indet.						
Corella eumyota	U					
Didemnum vexillum	C					
Perophora japonica	C					
Styela clava	U					
Bugula neritina	C					
Schizoporella japonica	C					
Tricellaria-Bugulina	C					
Watersipora subatra	C					
Celtodoryx ciocalyptoides	C					
Diadumene lineata	U					
Crepidula fornicata	U					
Ensis sp.	U					
Magallana gigas	U					
Rapana venosa	U					
Ruditapes sp.	U					
Urosalpinx / Ocenebra	U					
Ficopomatus enigmaticus	'C'					
Hydroides sp.	U					
Ammothea hilgendorfi	U					
(*Amphi-*)*Balanus* sp.	U					
Austrominius modestus	U					
Caprella mutica	U					
Dyspanopeus sayi	U					
Eriocheir sinensis	U					
Hemigrapsus sp.	U					
Hesperibalanus fallax	U					
Asparagopsis armata	U					
Bonnemaisonia hamifera	U					
Caulacanthus okamurae	U					
Chrysymenia wrightii	U					
Codium fragile fragile	U					

CONTINUED OVER

Appendix IX (ii) Summary Shore Survey Form (back)

Colpomenia peregrina	U					
Gracilaria spp.	U					
Grateloupia turuturu	U					
Pikea californica	U					
Sargassum muticum	U					
Undaria pinnatifida	U					

NATIVES	Score as **U**nitary or **C**olonial ↓	**Ab'd ce**	Field comments	Preserved		
			← 0, 1, 2, 3	Pot	Vial	ID comments incl. (Y/N)
Ascidiella sp.	U					
Botryllus schlosseri	C					
Dendrodoa grossularia	U					
Molgula sp.	U					
Morchellium argus	C					
Crisiid spp.	C					
Cryptosula pallasiana	C					
Oshurkovia littoralis	C					
Schizoporella unicornis	C					
Hymeniacidon perleve	C					
Actinia equina	U					
Urticina felina	U					
Littorina littorea	U					
Mytilus sp.	U					
Ostrea edulis	U					
Lanice conchilega	U					
Sabella pavonina						
Sabellaria sp.	'C'					
Spirobranchus sp.	U					
Carcinus maenas	U					
Pisidia longicornis	U					
Porcellana platycheles	U					
Semibalanus balanoides	U					
Verruca stroemia	U					
Cystoseira sp.	U					
Fucus serratus	U					
Fucus vesiculosus	U					
Halurus sp.						
Himanthalia elongata	U					
Laminaria digitata	U					
Saccharina latissima	U					
Ulva sp.	U					
Zostera sp.	C					

Appendix X (i): Environmental survey data - Shores

Site Code	Survey Date	Low tide [1]		Cloud cover %	Precipitation	Wind Beaufort No.	Wind direction [2]	WMO Sea state [3]		Pressure [4]	Air temp. (ºC) [4]	Sea temp. (ºC) [5]
		Time (BST)	Height (m)					Character	Code			
FTV SHR	16/05/2018	17:53	0.59	100	0	4	NE	Slight	3	1026	11	11.4
NSP SHR	17/05/2018	06:15	0.56	20	0	2	ENE	Smooth	2	1027	8	11.4
PKB SHR	17/05/2018	18:43	0.53	50	0	2	E	Smooth	2	1026	10	11.4
TAL SHR	18/05/2018	07:08	0.45	90	0	1	ENE	Calm	1	1026	8	11.4
GUB SHR	15/06/2018	06:12	0.43	30	0	3	WNW	Smooth	2	1017	12	13.6
CTB SHR	14/06/2018	05:24	0.40	100	0	3	WNW	Smooth	2	1017	15	13.6
BRL SHR	14/06/2018	17:58	0.80	5	0	3	WSW	Slight	3	1015	19	13.6
BLF SHR	13/06/2018	17:11	0.80	70	0	2	WSW	Calm	1	1015	13	13.6
SAP SHR	15/07/2018	19:20	0.80	5	0	3	WNW	Smooth	2	1015	23	15.4
BLP SHR	16/07/2018	07:46	0.60	20	0	2	SSW	Calm	1	1014	16	15.4
FTC SHR	16/07/2018	20:11	0.83	25	0	3	W	Slight	3	1014	22	15.4
ELS SHR	17/07/2018	08:37	0.68	50	0	3	WNW	Smooth	2	1017	16	15.4
RVC SHR	18/07/2018	09:28	1.05	70	0	3	E	Smooth	2	1019	15	15.3
HAC SHR	17/07/2018	21:00	1.17	50	0	3	SW	Slight	3	1018	17	15.3
STP SHR	20/05/2019	18:27	0.49	90	0	1	W	Calm	1	1015	14	11.4
INC SHR	21/05/2019	06:47	0.43	5	0	1	N	Calm	1	1016	14	11.4
MCH SHR	21/05/2019	19:05	0.65	50	0	2	W	Smooth	2	1019	13	11.4
DIB SHR	22/05/2019	07:25	0.57	80	0	1	N	Calm	1	1020	11	11.4
CHL SHR	19/06/2019	18:48	1.13	100	Lt drizzle	5	N	Slight	3	1009	15	13.4
HKS SHR	18/06/2019	18:10	1.04	100	Lt drizzle	2	N	Calm	1	1011	16	13.4
NET SHR	20/06/2019	07:03	0.95	10	0	3	W	Smooth	2	1013	11	13.4
WES SHR	19/06/2019	06:27	0.86	100	0	1	N	Calm	1	1008	14	13.4
OYS SHR	01/07/2019	16:21	0.95	20	0	2	NW	Calm	1	1022	17	15.6
NOR SHR	02/07/2019	17:08	0.77	20	0	1	N	Calm	1	1024	17	15.6
PCH SHR	03/07/2019	17:54	0.84	10	0	3	N	Smooth	2	1026	19	15.2
PAU SHR	04/07/2019	06:19	0.61	0	0	1	N	Calm	1	1027	10	15.2
SEA SHR	04/07/2019	18:48	0.80	0	0	2	S	Calm	1	1022	22	15.2
RYD SHR	05/07/2019	07:02	0.59	50	0	2	N	Calm	1	1020	12	15.2

Appendix X (ii): Environmental survey data - Marinas

Site Code	Survey Date	Pressure [4]	Air temp. (ºC) [4]	Sea temperature(ºC) [6]		Salinity [6]		Turbidity (Secchi depth) m
				Surface	2m	Surface	2m	
YAR MAR	17/05/2018	1026	14	12.8	12.7	34.4	34.2	2.3
LYH MAR	18/05/2018	1025	12	15.1	14.5	33.1	33.3	2.1
CYH MAR	15/06/2018	1018	16	17.4	17.3	34.6	34.5	1.7
BEM HBR	14/06/2018	1013	19	16.8	16.9	34.9	34.8	2.0
SPK MAR	16/07/2018	1013	25	23.0	22.3	35.6	35.2	3.0
SOU MAR	17/07/2018	1017	20	21.5	21.5	35.3	35.3	1.0
HAP MAR	18/07/2018	1018	22	21.6	21.5	33.7	33.8	2.0
BUK MAR	21/05/2019	1018	16	16.1	16.0	31.2	31.3	1.0
HYT MAR	22/05/2019	1021	15	16.7	15.7	31.8	31.1	2.6
WAR HBR	19/06/2019	1008	17	16.1	16.0	32.8	32.9	1.2
OCN MAR	20/06/2019			16.6	16.5	26.7	31.5	3.3
NOR MAR	02/07/2019			20.2	20.0	34.8	34.8	2.2
PSL MAR	03/07/2019	1027	19	21.5	21.2	34.6	34.4	2.6
PSL MAR	03/07/2019	1027	19	19.8	19.5	34.9	35.0	1.8
RYD MAR	05/07/2019	1020	20	22.5	22.1	35.1	35.0	>0.9

Notes:

Cloud cover, precipitation, wind speed, marina sea temperature, salinity and turbidity from personal observation.

[1] Tidal times and heights from POLTIPS

[2] Wind direction from personal observation and www.timeanddate.com/weather

[3] Sea state from personal observation and images

[4] Pressure and air temperature from www.timeanddate.com/weather/uk

[5] Sea temperature (shores) from www.seatemperature.org/europe/united-kingdom

[6] Sea temperature and salinity (marinas/harbours) YSI 30 Salinometer

Appendix XI: Proposed Alien Species target lists

Species	UK MSFD Lists	List A Professional staff	List B Volunteers or Citizen Scientists
Asterocarpa humilis	Y	Y	Y
Botrylloides violaceus		Y	
Botrylloides diegensis		Y	Y
Corella eumyota		Y	Y
Didemnum vexillum	Y	Y	Y[1]
Styela clava	Y	Y	Y
Bugula neritina		Y	Y
Tricellaria inopinata		Y	
Watersipora subatra		Y	Y
Arcuatula senhousia		Y	Y
Crepidula fornicata	Y	Y	Y
Magallana gigas	Y	Y	Y
Ocinebrellus inornatus	Y	Y	
Rapana venosa	Y	Y	
Urosalpinx cinerea	Y	Y	
Ficopomatus enigmaticus	Y	Y	
Hydroides ezoensis		Y	Y
Amphibalanus amphitrite	Y	Y	
Austrominius modestus		Y	Y
Hemigrapsus sanguineus	Y	Y	Y[1] (combined)
Hemigrapsus takanoi	Y	Y	
Sargassum muticum	Y	Y	Y
Undaria pinnatifida	Y	Y	Y
Asparagopsis armata		Y	Y
Caulacanthus okamurae		Y	Y
Gracilaria vermiculophylla	Y	Y	
Grateloupia turuturu	Y	Y	Y
Codium fragile fragile		Y	

Notes: Both lists are suitable for use in the Solent region. They have been designed to detect those AS most likely to affect the ecosystem and thus a site's environmental status. They include species that are already established in the region and other horizon species that are either present elsewhere in the UK or in Europe that are likely to have an impact.

List A could be used by experienced surveyors with some access to additional resources e.g. taxonomic support or a microscope.

List B relies completely on field identification by non-professionals but who have received basic training and some resources e.g. descriptions and images of AS, and likely confusion species.

[1] Any putative records should always be referred to the MBA for ID confirmation.

Appendix XII: Landowner site-specific alien species lists

NNS recorded at XXXXXX shore on 25/06/2018

Natural England and the Bishop Group of the Marine Biological Association of the UK have been carrying out Rapid Assessment Surveys (RAS) for invasive alien species (IAS) at marina and shore sites in the Solent area over the last two years, funded by a European Maritime and Fisheries Fund grant.

Ten records of NNS were generated from XXXXXXX. This is typical for shores in the Solent area (average X.X). Specifically, *Magallana gigas* (Pacific oyster) is very abundant and it could present a hazard to visitors to the shore.

Report prepared by:

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Additional sources of information:

RAPID LIFE website (biosecurity advice): http://www.nonnativespecies.org/index.cfm?pageid=621

GB Non-native Species Information Portal: http://www.nonnativespecies.org/factsheet/

Bishop Group website: https://www.mba.ac.uk/bishop/

NATURAL ENGLAND

European Union
European Structural and Investment Funds

THE MARINE BIOLOGICAL ASSOCIATION
Est. 1884
Incorporated by Royal Charter

Appendix XII (ii): Landowner site-specific alien species lists

Scientific name	Common name	2018
Sea squirts		
Aplidium cf. glabrum		
Asterocarpa humilis	Compass sea squirt	
Botrylloides violaceus	Orange cloak sea squirt	
Botrylloides diegensis	San Diego sea squirt	
Ciona robusta		
Corella eumyota	Orange-tipped sea squirt	✓
Didemnum vexillum	Carpet sea squirt	✓
Perophora japonica	Creeping sea squirt	
Styela clava	Leathery sea squirt	✓
Sea mats (Bryozoans)		
Bugula neritina	Ruby bryozoan	
Bugulina fulva		
Bugulina simplex		
Bugulina stolonifera		✓
Schizoporella japonica	Orange ripple bryozoan	
Tricellaria inopinata	Tufty-buff bryozoan	✓
Watersipora subatra	Red ripple bryozoan	
Barnacles		
Austrominius modestus	Darwin's barnacle	✓
Amphibalanus amphitrite	Striped barnacle	
Amphibalanus improvisus	Bay barnacle	
Hesperibalanus fallax		
Molluscs		
Arcuatula senhousia	Asian date mussel	
Crepidula fornicata	Slipper limpet	✓
Ensis leei	American jackknife clam	
Magallana gigas	Pacific oyster	✓
Mercenaria mercenaria	American hard-shelled clam	
Ocinebrellus inornatus	Japanese oyster drill	
Rapana venosa	Veined rapa whelk	
Ruditapes philippinarum	Manila clam	
Urosalpinx cinerea	American oyster drill	

Scientific name	Common name	2018
Tube worms		
Ficopomatus enigmaticus	Trumpet tube worm	
Hydroides dianthus		
Hydroides elegans		
Hydroides ezoensis		✓
Crabs		
Dyspanopeus sayi	Say's mud crab	
Eriocheir sinensis	Chinese mitten crab	
Hemigrapsus sanguineus	Asian shore crab	
Hemigrapsus takanoi	Brush-clawed crab	
Other animals		
Ammothea hilgendorfi	Japanese sea spider	✓
Caprella mutica	Japanese skeleton shrimp	
Celtodoryx ciocalyptoides	Cauliflower sponge	
Diadumene lineata	Orange-striped anemone	
Brown Seaweeds		
Colpomenia peregrina	Oyster thief	
Sargassum muticum	Wireweed	
Undaria pinnatifida	Wakame	
Red Seaweeds		
Asparagopsis armata	Harpoon weed	
Bonnemaisonia hamifera	Hook weed	
Caulacanthus okamurae	Pom-pom weed	
Chrysymenia wrightii	Golden membrane weed	
Gracilaria vermiculophylla	Worm wart weed	
Grateloupia turuturu	Devil's tongue weed	
Melanothamnus harveyi		
Pikea californica		
Solieriaceae		
Green Seaweeds		
Codium fragile fragile	Green sea fingers	
Umbraulva dangeardii		

Appendix XIII (i): Alien and Native Species occurrence data at each site

SITE CODE	FTV SHR	NSP SHR	YAR MAR	PKB SHR	TAL SHR	LYH MAR	GUB SHR	CTB SHR	CYH MAR	BRL SHR	BLF SHR	BEM HBR	SAP SHR	BLP SHR	SPK MAR	FTC SHR	ELS SHR	SOU MAR	RVC SHR	HAC SHR	HAP MAR	STP SHR	INC SHR	BUK MAR	MCH SHR	DIB SHR	HYT MAR	CHL SHR	HKS SHR	WAR HBR	NET SHR	WES SHR	OCN MAR	OYS SHR	NOR SHR	NOR MAR	PCH SHR	PAU SHR	PSL MAR	SEA SHR	RYD SHR	RYD MAR
Far/Near/Marina	F	N	M	F	N	M	F	N	M	F	N	M	F	N	M	F	N	M	F	N	M	F	N	M	F	N	M	F	N	M	F	N	M	F	N	M	F	N	M	F	N	M
ALIEN SPECIES																																										
Styela clava	N	R	R	F	F	F	N	R	F	N	R	N	N	R	R	R	R	R	R	R	A	R	R	R	N	N	N	R	R	A	A	R	A	A	F	F	N	F	N	R	R	N
Asterocarpa humilis	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	R	N	N
Ciona robusta	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
Corella eumyota	N	N	F	N	R	R	N	N	R	R	N	R	N	N	N	N	R	R	R	N	R	N	R	N	N	N	N	N	N	F	N	N	N	R	R	F	N	R	N	R	R	N
Botrylloides violaceus	N	N		N	R	R	N		R			N	N	N	R	N	N		N	N	R	N	N	R	N	N	N	N	N	R	R	N	A	F	F	F	N	R	N	N	N	N
Botrylloides diegensis	N	N	R	N	R	R	N	R	F	N	N	N	N	R	A	F	R	F	N	N	A	R	F		N	N	N	N	N	R	N	N	N	A	A	A	R	R	R	R	R	N
Didemnum vexillum	N	N	F	N	N	N	N	N	R	N	N	N	N	R	F	R	N	N	N	N	R	N	N	N	N	N	N	N	N	R	N	N	N	F	R	F	N	N	N	N	N	N
Perophora japonica	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	R	N	N	N	F	R	N
Aplidium cf. *glabrum*	N	N	R	N	N	R	R	R	R	N	R	N	N	R	R	R	R	R	N	N	R	N	N	N	N	N	N	N	N	R	N	N	R	F	R	R	N	R	R	F	N	N
Bugula neritina	N	N	R	N	N	N	N	N	R	N	N	N	N	R	A	R	N	A	R	N	A	N	N	N	N	N	R	N	N	F	F	N	A	R	R	A	N	R	A	N	N	N
Watersipora subatra	N	N	F	N	N	N	N	R	R	R	R	N	N	N	R	R	R	R	N	N	R	N	N	N	N	N	N	N	N	A	N	N	R	N	R	R	N	R	R	R	R	N
Schizoporella japonica	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
Tricellaria inopinata	N	R	R	R	R	F	R	R	F	R	N	N	N	F	A	R	F	F	R	F	A	N	R	N	N	N	N	N	R	A	R	R	A	R	F	A	N	R	R	F	A	N
Bugulina simplex	N	N	N	N	N	R	N	N	N	N	N	N	N	N	R	N	N	F	N	N	N	N	N	N	N	N	F	N	N	N	N	N	N	N	N	R	N	R	F	N	N	N
Bugulina stolonifera	N	N	N	N	N	N	N	N	R	N	N	N	N	R	N	N	N	R	N	N	R	N	N	N	N	N	F	N	R	R	R	N	R	N	N	R	N	R	R	N	N	N
Bugulina fulva	N	R	R	N	N	R	F	F	F	N	F	N	N	N	R	R	N	R	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	R	N	N	N	R	N	N
Celtodoryx ciocalyptoides	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
Diadumene lineata	N	N	N	N	N	N	N	N	N	N	N	R	N	N	N	N	N	N	N		N	N	N	N	R	N	R	N	N	N	N	N	N	N	N	R	N	N	R	N	N	N
Austrominius modestus	R	R	R	F	R	R	R	R	R	N	R	F	F	F	R	A	A	R	F	A	R	F	R	F	F	A	R	F	A	F	F	A	A	A	F	N	A	A	R	F	F	F
Amphibalanus amphitrite	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	R	N	N	N	A	N	N	N	N	N	N	N	N	N	N	R	F	N	N	N
Amphibalanus improvisus	N	N	N	N	N	R	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	F	N	R	N	N	N	N	R	N	N	N	N	N	N	N	N	N	N	N
Hesperibalanus fallax	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
Caprella mutica	N	N	N	N	N	N	N	R	R	N	N	N	N	N	R	N	N	N	N	N	A	N	N	N	N	N	N	N	R	A	N	N	A	N	N	N	N	N	R	N	N	N
Hemigrapsus sanguineus	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
Hemigrapsus takanoi	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
Dyspanopeus sayi	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
Eriocheir sinensis	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
Ammothea hilgendorfi	R	R	R	R	R	N	N	R	R	N	N	N	N	R	R	F	R	N	F	R	R	R	R	R	N	R	N	R	N	F	R	R	R	R	R	R	R	R	N	N	N	N
Crepidula fornicata	R	F	N	R	A	N	N	N	R	N	N	N	R	N	R	R	F	N	F	A	R	F	R	F	F	A	N	F	R	R	R	F	R	R	F	N	N	N	N	R	F	N
Crepidula fornicata (dead)	R			F			R			R	R		F	F															R					R			R					
Urosalpinx cinerea	N	N		N	N		N	N		N	N		N	N		N	N		N	N		N	N		N	N		N	N		N	N		N	N		N	N		N	N	
Ocinebrellus inornatus	N	N		N	N		N	N		N	N		N	N		N	N		N	N		N	N		N	N		N	N		N	N		N	N		N	N		N	N	
Rapana venosa	N	N		N	N		N	N		N	N		N	N		N	N		N	N		N	N		N	N		N	N		N	N		N	N		N	N		N	N	
Arcuatula senhousia (dead)																											R															
Magallana gigas	N	N	R	N	N	N	N	N	N	N	N	N	N	N	N	N	N	R	A	F	R	N	N	R	A	A	F	R	F	R	A	A	R	R	F	N	R	N	R	N	R	N
Magallana gigas (dead)				F	R		R						R	R					A																							
Mercenaria mercenaria																			P																							
Mercenaria mercenaria (dead)																							P					P	P			P		P								
Ruditapes philippinarum				P	P														P	P								P														
Ruditapes philippinarum (dead)	P			P									P	P		P	P		P	P		P	P			P		P	P		P	P		P	P		P	P				
Ensis leei																																										
Ficopomatus enigmaticus	N	N	N	N	N	A	N	N	N	N	N	A	N	N	N	N	N	R	R	R	R	N	N	N	A	F	R	N	R	N	R	F	A	R	R	R	N	R	R	N	N	N
Hydroides dianthus	N	N	N	N	N	N	N	N	N	N	N	N	N	N	R	R	N	R	N	N	N	N	N	R	N	N	N	N	N	N	N	N	N	R	R	R	N	R	N	N	N	N
Hydroides ezoensis	N	N	R	N	R	F	R	R	R	N	N	N	N	N	R	R	R	R	F	A	F		N	R	A	A	R	F	F	F	A	F	F	F	R	R	R	A	N	N	N	N
Hydroides elegans	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
Undaria pinnatifida	N	N	R	N	N	N	N	R	A	N	N	N	N	R	R	N	N	R	N	N	F	N	N	N	N	R	N	N	R	A	R	R	F	N	R	R	N	N	N	N	N	N
Sargassum muticum	F	A	F	F	F	R	F	F	R	A	A	R	N	F	R	F	A	R	N	R	R	A	F	F	N	N	N	R	A	F	R	N	R	F	F	R	N	N	N	A	A	N
Grateloupia turuturu	N	N	F	F	R	R	N	N	R		N	N	N	N	R	N	R	R	R	R	F	A	R	R	N	R	N	A	R	F	R	R	N	R	R	R	N	N	R	N	N	N
Asparagopsis armata	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
Gracilaria vermiculophylla																																										
Codium fragile	N	N	N	N	N	N	N	N	N	F	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	R	R	N
Colpomenia peregrina	R	F	N	F	R	N	N	R	R	F	F	N	N	N	R	N	N	N	N	N	N	R	R	N	N	R	N	N	R	R	R	R	N	N	R	R	N	N	N	R	R	R
Bonnemaisonia hamifera	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
Caulacanthus okamurae	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
Chrysymenia wrightii	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
Pikea californica	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
Umbraulva dangeardii									R																																	
Melanothamnus harveyi																							F																			
Solieriaceae																			R	R								R	R		R			R	R					R	R	

Appendix XIII (ii): Alien and Native Species occurrence data at each site

SITE CODE	FTV SHR	NSP SHR	YAR MAR	PKB SHR	TAL SHR	LYH MAR	GUB SHR	CTB SHR	CYH MAR	BRL SHR	BLF SHR	BEM HBR	SAP SHR	BLP SHR	SPK MAR	FTC SHR	ELS SHR	SOU MAR	RVC SHR	HAC SHR	HAP MAR	STP SHR	INC SHR	BUK MAR	MCH SHR	DIB SHR	HYT MAR	CHL SHR	HKS SHR	WAR HBR	NET SHR	WES SHR	OCN MAR	OYS SHR	NOR SHR	NOR MAR	PCH SHR	PAU SHR	PSL MAR	SEA SHR	RYD SHR	RYD MAR
Far/Near/Marina	F	N	M	F	N	M	F	N	M	F	N	M	F	N	M	F	N	M	F	N	M	F	N	M	F	N	M	F	N	M	F	N	M	F	N	M	F	N	M	F	N	M
NATIVES SPECIES ACTIVELY RECORDED																																										
Ascidia conchilega	N	N	N	N	N	N	N	N	F	N	R	N	N	N	F	R	R	R	R	N	R	N	F	R	N	N	N	N	N	R	F	N	N	F	N	F	N	F	N	N	N	N
Ascidia mentula	N	N	N	N	N	N	R	N	N	R	R	N	N	N	N	N	N	N	N	N	N	R	N	N	N	N	N	R	R	N	N	N	N	N	N	N	N	N	N	N	R	N
Ascidiella aspersa	N	N	A	N	R	F	N		A	N	N	R	R	F	A	A	F	A	R	R	F	R	R	N	N	N	F	R	R	R	F	N	R	F	F	A	N	R	A	N	R	N
Ascidiella scabra	N	N	N	N	N	N	N		N	R	N	N	N	N	N	N	N	N	N	N	N	R	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
Botryllus schlosseri	N	N	R	R	R	F	R	R	R	R	R	N	N	R	R	R	R	R	R	R	R	R	R	R	N	N	F	N	N	R	R	R	F	R	R	R	N	R	A	R	R	N
Ciona intestinalis	N	N	A	N	R	F	R	N	F	R	N	R	R	N	F	R	R	A	R	N	F	R	R	R	N	N	A	N	R	R	R	R	R	R	R	A	N	R	F	R	N	N
Clavelina lepadiformis	N	N	R	N	N	R	N	N	N	N	R	N	N	N	R	R	N	R	N	N	R	N	N	N	N	N	F	N	N	N	N	N	N	N	N	R	N	N	R	R	N	N
Dendrodoa grossularia	N	N	R	F	F	N	R	R	R	N	R	N	N	N	N	R	R	N	R	R	N	R		N	N	N	N	R	R	N	N	R	R	R	N	R	N	N	N	N	N	N
Diplosoma listerianum	N	N	R	N	N	N	N	N	R	R	N	N	N	R	A	R	N	F	N	N	R	N	N	N	N	N	A	N	N	R	N	N	N	N	N	F	N	N	R	N	N	N
Molgula	R	R	F	N	N	F	R	R	F	R	N	R	R	N	N	R	N	R	R	R	F	N	N	A	N	N	N	R	R	R	R	N	R	R	R	R	N	R	R	R	R	N
Morchellium argus	N	N	N	R	N	N	N	R	F	F	F	N	N	N	N	R	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	R	N	N	N	R	R	N
Bugulina flabellata	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
Crisularia plumosa	N	R	N	N	N	N	F	F	F	N	R	N	N	N	N	F	N	N	R	N	R	N	N	N	N	N	N	N	N	N	N	N	R	N	N	N	N	N	N	R	N	N
Bugulina turbinata	N	N	N	N	N	N	R	F	N	N	R	N	N	N	N	R	R	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
Celleporella hyalina			N			N			N			N			N			N			N															N					R	
Conopeum reticulum	R		F						R	R		R	R	R			R		R	R	R	R	R	R	R			R	R	F	R		R	R		N		R		F	R	
Conopeum seurati						F						A									N			R	R		R				R		R	R		N		R	R			
Einhornia crustulenta																								R																		
Cryptosula pallasiana	N	R	R	R	R	R	R	N	R	R	R	N	R	R	R	R	F	R	R	R	R	R	R	N	N	N	R	R	R	F	R	R	R	R	R	R	N	N	R	F	R	N
Electra pilosa			R		R	R	R	R	F		R	R	R	R	R	R	R	N	R	R	R	R	R					R	R	F			R			N				F	R	R
Oshurkovia littoralis	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
Schizoporella unicornis	R	N	N	N	N	N	N	N	N	R	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
Scrupocellaria scruposa	N	R	R	N	N	N	F	R	R	N	N	N	N	N	R	N	N	N	N	R	N	N	N	R	N	N	N	N	R	R	R	N	N	N	N	N	N	N	N	N	N	N
Hymeniacidon perlevis	R	R	R	R	F	R	F	R	R	R	F	N	N	N	R	R	R	R	R	R	N	R	F	R	F	R	R	R	R	R	A	R	R	F	F	N	R	F	N	R	N	N
Sycon ciliatum	N	N	A	N	N	R	R	R	F	R	N	R	N	R	R	R	R	F	N	N	R	R	R	R	N	N	N	N	N	R	F	N	F	R	R	R	N	R	R	N	N	N
Actinia equina	R	R	N	R	R	N	R	R	N	R	R	N	N	N	N	N	N	N	R	N	N	R	N	N	N	N	N	R	R	N	N	N	N	R	N	N	N	F	N	F	R	N
Metridium senile			R			N			R			N			N			R			N															N						
Urticina felina	R	N	N	R	N	N	N	N	N	R	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
Littorina littorea	N	F		A	A		R	R		R	R		R	R		R	F		A	A		A	F		F	A		A	A		A	A		F	F		F	F		R	R	R
Ocenebra erinaceus	N	N		R	R		N	R		N	R		N	N		N	N		R	R		F	R		N	N		R	R		R	R		R	R		N	R		R	N	
Mytilus	N	R	R	R	N	R	R	N	R	N	N	F	R	R	R	R	N	N	R	R	F	R	N	F	F	F	F	N	R	F	R	R	F	R	N	N	N	R	R	R	N	R
Ostrea edulis	N	N	N	N	R	R	N	N	N	N	N	N	N	N	R	R	R	N	R	R	R	N	R	R	R	R	N	R	N	N	R	R	R	R	R	R	N	R	R	N	N	N
Ostrea edulis (dead)					R								R	R		F				R		R												R			R			R	R	
Arenicola	P										P			P		P	P		P	P		P	P					P	P		P	P					P			P	P	
Hydroides norvegica	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
Lanice conchilega	F	A		R	R		F	R		R	N		N	F		R	R		R	R		F	N		F	R		F	F		F	R		N	N		N	N		R	R	
Sabella pavonina	N	N	R	R	R	R	R	N	R	N	N	N	N	R	R	N	R	R	N	N	N	N	N	N	N	N	N	N	N	N	N	N	R	R	N	R	N	N	N	N	N	N
Sabellaria	N	N		N	N		N	N		N	N		N	N		N	N		N	N		N	N		N	N		N	R		N	N		N	N		N	N		N	N	
Spirobranchus	F	F	R	R	R	N	F	R	R	R	F	R	R	N	R	F	F	R	A	A	F	F	R	N	F	R	N	A	R	R	F	R	R	R	R	R	R	R	A	R	F	N
Spirorbinae			R			R			R	F	A	N		R	R	R	A	A		R	R	R	R	F			F	R	R					A	A	R	A	A		A	R	
Carcinus maenas	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	F	F	F	R	R	F	R	R	F	F	N	F	R	R	F	F	R	A	F	R	R	N	R	R	R	R
Pisidia longicornis	F	R	N	R	R	R	R	R	R	R	R	N	N	N	R	R	R	R	R	R	R	R	N	N	N	N	N	R	R	R	R	N	N	N	N	R	N	N	N	R	R	N
Porcellana platycheles	R	R	N	R	N	N	F	F	N	F	R	N	N	N	N	R	R	N	R	R	R	R	R	N	N	R	N	R	R	R	F	R	N	F	N	R	N	R	N	R	N	N
Balanus crenatus	R	F	R	R	N	R	A	F	R	N	R	F	N	N	N	F	N	N	R	R	R	R	R	R	R	R	N	R	R	R	R	R	F	N	N	N	N	R	N	R	N	N
Semibalanus balanoides	F	F	R	F	F	N	F	F	R	F	A	F	F	F	R	F	R	R	F	A	R	R	R	N	R	F	N	A	A	R	F	R	R	F	F	R	A	R	R	A	R	F
Verruca stroemia	N	N	N	N	N	N	N	R	N	N	R	N	N	N	N	N	N	N	N	N	N	R	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
Cystoseira	N	N		N	N		N	N		N	N		N	N		N	N		N	N		N	N		N	N		N	N		N	N		N	R	R	N	N		R	A	
Fucus			R			R			R			R			R			R			R						N						R			R			N			N
Fucus serratus	A	F		R	N		F	F		A	A		N	N		A	F		N	R		F	F		F	F		R	N		R	R		F	R		N	F		A	R	
Fucus spiralis																R				R			F			R											F					
Fucus vesiculosus	F	R		R	N		N	R		R	F		N	R		N	F		N	N		F	F	R	A	F		F	R	R	R	F		A	A		A	A		A	F	R
Fucus ceranoides				A	F																				R																	R
Gracilaria	A	R		F	R		F	R		R	R		F	F		R	R		A	R		F	F		R	N		R	R		F	N		N	R		R	N		N	N	
Halurus	N	N	N	N	N	N	F	A	F	F	F	N	N	R	R	R	F	R	R	R	N	F	F	N	R	N	N	F	F	R	F	R	N	F	A	R	F	R	R	R	R	N
Himanthalia elongata	N	N		N	N		N	N		N	R		N	N		N	N		N	N		N	N		N	N		N	N		N	N		N	N		N	N		N	N	
Laminaria digitata	R	N	R	N	N	N	N	N	N	R	F	N	N	R	R	R	R	R	N	N	R	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
Saccharina latissima	F	F	A	R	R	N	N	R	R	R	R	N	N	N	R	R	R	R	R	R	R	R	N	N	N	N	R	R	R	N	N	N	N	N	N	N	N	N	N	R	F	N
Ulva	A	A	F	F	F	A	F	F	F	R	A	A	R	R	F	A	A	R	A	A	F	F	F	F	A	A	A	A	A	A	R	A	A	A	A	A	F	A	R	A	F	F
Zostera	N	A		N	N		N	R		F	F		N	N		N	N		N	N		R	N		N	N		N	N		N	N		N	N		F	N		N	F	

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