

# Mapping Invasive Non-Native Species on the River Itchen - 2022

February 2026

Natural England Commissioned Report NECR686

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## Report details

### Author(s)

John D. D. Bishop - The Marine Biological Association

Christine A. Wood – The Marine Biological Association

Jessica G. Taylor – Natural England

### Natural England Project Manager

Jessica Taylor

### Contractor

The Marine Biological Association of the UK

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# Foreword

In 2017 The Marine Biological Association undertook a series of surveys to map the presence of Invasive Non-Native Species (INNS) along the estuary of the River Itchen, Hampshire, from its tidal limit at Woodmill, down to Dock Head where it meets Southampton Water.

Natural England commissioned this project to determine whether there has subsequently been any onward colonisation of INNS, and in particular the Red-ripple bryozoan, (*Watersipora subatra*), an invasive bryozoan which has been shown to be spreading widely in the Solent (and elsewhere) and was recorded at only one site at the mouth of the River Itchen.

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# Executive summary

Estuaries are habitat complexes which comprise an interdependent mosaic of subtidal and intertidal habitats, many of these habitats, e.g. mudflats, saltmarshes, and reefs, are identified as Annex I habitat types in their own right. The UK has over 90 estuaries, several of which are designated for protection of specific species or features, as Special Areas of Conservation (SAC), Special Protection Areas (SPAs), or Sites of Special Scientific Interest (SSSIs). The Good Environmental Status (GES) of these sites may be threatened by the presence of Invasive Non-Native Species (INNS).

Harbours, marinas and aquaculture facilities are frequently located in estuaries and are potential entry points for marine Non-Native Species (NNS). There is little systematic information on the relative tolerance of different NNS to estuarine conditions and their penetration landwards along estuarine gradients. This lack of knowledge means it is difficult to communicate the scale of risk from NNS, limiting the marine sector's ability to take proactive management action such as promoting biosecurity plans and implementing good practice to prevent NNS impacting the marine ecosystem and commercial activities. An understanding of NNS distribution along estuarine gradients would contribute to biosecurity planning by allowing assessment of the risk posed by individual NNS at specific locations within an estuary, for instance, in Marine Protected Areas (MPAs) or at sites proposed for new infrastructure developments.

The Itchen estuary is part of the Lee-on-The Solent to Itchen Estuary SSSI. It is heavily constrained by a mix of waterside developments and contains several marinas, sailing centres and boatyards. Above Northam Bridge, there are numerous smaller establishments; residential properties, many with private pontoons or piers; and recreational parkland.

In 2017 The Marine Biological Association (MBA) carried out rapid assessment surveys (RAS) at a number of sites along the estuaries of the R. Itchen and the R. Hamble in the Solent, as part of a wider study into the distribution of NNS in estuaries in southern England. The R. Itchen was surveyed from its tidal limit at Woodmill, down to where it meets Southampton Water.

Natural England commissioned the work reported here to determine whether there has subsequently been any onward colonisation of INNS within the R. Itchen, and in particular of the Red-ripple bryozoan (*Watersipora subatra*), an invasive bryozoan which has been shown to be spreading widely in the Solent (and elsewhere) and was recorded at only one site at the mouth of the R. Itchen in 2019, subsequent to the baseline surveys in 2017.

Re-survey of the Itchen confirmed the general pattern of succession of NNS in the estuary and added four NNS to the list of those recorded in 2017. The failure of *Watersipora subatra* to encroach further on the estuary over a period of five years was documented, and a remarkable increase in NNS at one site was detected.

No statistically significant overall increase in the presence of NNS in the Itchen was detected between 2017 and 2022, either in terms of the number of NNS per site or the number of sites occupied per NNS. Similarly, there was no significant overall movement of the calculated centres of distribution of the 20 species that were recorded in both 2017 and 2022. Despite these overall conclusions, a remarkable increase of 10 NNS was recorded between 2017 and 2022 at one particular mid-estuary marina site, SXW. This site thereby became the upstream limit of eight of the 18 species recorded there in 2022. It seems possible that this apparent influx might reflect the introduction of species from a downstream site as fouling on a vessel or repositioned infrastructure such as pontoons.

The Carpet Sea-squirt (*Didemnum vexillum/pseudovexillum*) and the Asian date mussel (*Arcuatula senhousia*), both single-site occurrences, had not previously been recorded in the R. Itchen so were added to the list of NNS from the 2017 survey.

*W. subatra* had not spread into the estuary by 2022, being found only as a single colony at a single site. Assessment of existing records of its occurrence in southern England with regard to salinity suggested the species should be able to occupy the polyhaline zone of estuaries and thus colonise some way into the Itchen estuary (potentially almost to the Northam (A3024) road bridge), so its failure to establish is still largely unexplained.

A statistical cluster analysis of sites based on their respective NNS assemblages divided the estuary into two distinct groups of sites that respectively occupied the estuary above and below the Northam Road bridge and were estimated to equate approximately to the mesohaline and polyhaline zones of the estuary in the Venice classification<sup>1</sup>. A rapid reduction of NNS diversity from around 16 to just six remaining species in the mesohaline zone occurred moving upstream towards this boundary.

Adequate knowledge of the salinity regime enables biological observations of NNS distribution in an estuary to be placed into a general framework, allowing direct comparison of different water bodies and potentially the description of common patterns, with the ultimate aim of making useful predictions of the risk from particular NNS at different locations along the estuarine gradient.

The MBA has unpublished data of NNS surveys in a number of other estuaries (Hamble, Dart, Teign, Tamar, Plym, Yealm, and Fal) from 2018 to 2021. Consideration should be given to whether repeat surveys could provide useful information to aid understanding of patterns and processes of colonisation of these important sites.

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<sup>1</sup> The Venice system is a widely recognised classification scheme for marine and coastal waters based on salinity levels.

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

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# 1 Introduction

Non-native species, abbreviated here to NNS, 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. 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 non-native species' (INNS).

Biological invasions by INNS 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 and others, 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 marine NNS into the UK due to its high volumes of international shipping and recreational boating, both major vectors of INNS. These INNS 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.

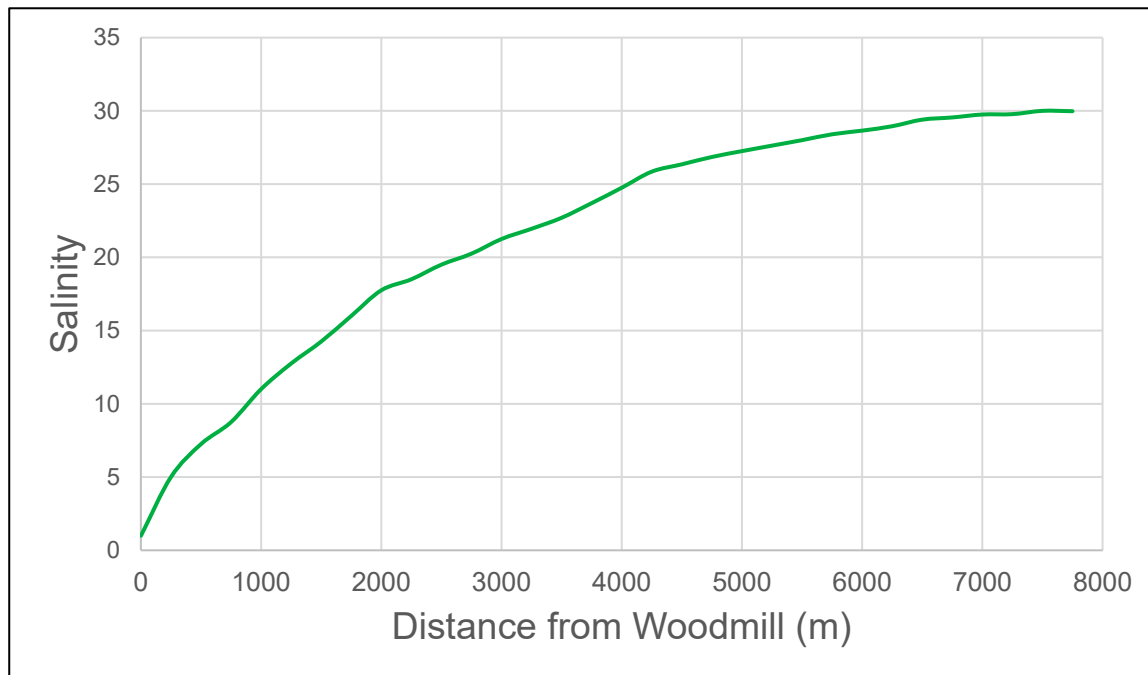
Estuaries are habitat complexes which comprise an interdependent mosaic of subtidal and intertidal habitats, many of these habitats, e.g. mudflats, saltmarshes, and reefs, are identified as Annex I habitat types in their own right. The UK has over 90 estuaries, several of which are designated for protection of specific species or features, as Special Areas of Conservation (SAC), Special Protection Areas (SPAs), or Sites of Special Scientific Interest (SSSIs). The Good Environmental Status (GES) of these sites may be threatened by the presence of INNS.

Harbours, marinas and aquaculture facilities are frequently located in estuaries and are potential entry points for marine NNS. There is little systematic information on the relative tolerance of different NNS to estuarine conditions and their penetration landwards along estuarine gradients. This information would contribute to biosecurity planning by allowing assessment of the risk posed by individual NNS at specific locations within an estuary, for instance in MPAs or at sites proposed for new infrastructure developments.

Southampton Water is a typical estuarine environment, with three main tributaries, the rivers Test, Itchen and Hamble. The Itchen estuary is part of the Lee-on-The Solent to Itchen Estuary SSSI. It is heavily constrained by a mix of waterside developments, and contains several marinas, sailing centres and boatyards. Above Northam Bridge, there are numerous smaller establishments; residential properties, many with private pontoons or piers; and recreational parkland.

The Itchen Estuary is about 200 - 400 m wide and 7.8 km long. The water depth is approximately 0 m (local Chart Datum) at Woodmill, the tidal limit, increasing to 9 m at Dock Head, where the Test Estuary and Itchen Estuary meet Southampton Water (Shi, 2000). The salinity distribution in the tidally dominant Itchen Estuary has a semi-diurnal cycle and a half-monthly spring-neap cycle and is also influenced by the seasonal

variation of the riverine freshwater discharge. The salinity range between Woodmill and Dock Head is 0 - 32 psu. The surface salinity increases rapidly downstream in the upper parts of the Itchen Estuary from Woodmill to Northam Bridge (2.8 km downstream). The farther the point from the fresh water source, the less the salinity variation: at Woodmill the salinity ranges (at all depths) from 0 - 20 psu, whereas at Dock Head the range is about 25 - 32 psu (Shi, 2000). A 3-D water quality model of Southampton Water and the Itchen Estuary has been developed that includes the predicted salinity distribution within the Itchen Estuary at different periods in the tidal cycles and seasons (Shi, 2000). Figure 1 is a simplified time-averaged and seasonally averaged interpretation of that model.



**Figure 1: Longitudinal time-averaged and seasonally averaged surface salinity distribution along the main channel of the Itchen Estuary from Woodmill to Dock Head. Adapted from data modelled in Shi (2000).**

In 2017 The Marine Biological Association (MBA) carried out rapid assessment surveys (RAS) at a number of sites along the estuaries of the R. Itchen and the R. Hamble in the Solent as part of a wider study into the distribution of NNS in estuaries in Southern England. The R. Itchen was surveyed from its tidal limit at Woodmill, down to where it meets Southampton Water at Dock Head.

Natural England commissioned the work reported here to determine whether there has subsequently been any onward colonisation of INNS within the R. Itchen, and in particular of the Red-ripple bryozoan (*Watersipora subatra*), an invasive bryozoan which has been shown to be spreading widely in the Solent (and elsewhere) and was recorded at only one site at the mouth of the R. Itchen in 2019 (Taylor, Wood & Bishop, 2022), subsequent to the baseline surveys in 2017.

This project had the following aims:

- Plan and undertake rapid assessment surveys of a target list of NNS at up to 20 locations on the River Itchen, following the same methodology as employed in earlier surveys and visiting the same sites as far as possible to allow comparisons between the data sets;
- Analyse the resulting data and information from these and the previous surveys;
- Review possible changes in species' prevalence in terms of distribution and abundance.

## 2 Methods

The surveys carried out in 2022 were designed to repeat the surveys previously undertaken in the R. Itchen in 2017 by the MBA. Those surveys were part of a larger study designed to elucidate the distribution of NNS along the estuarine gradient, and the extent of spread of marine NNS in estuaries within the UK (J. Bishop & C. Wood unpublished data, 2017 - 2021).

### 2.1 Site selection

In 2017, the sites surveyed were a mixture of floating structures, shore sites, and buoys floating in the river that were accessed by boat.

- Those sites were chosen using the following criteria:
- To provide good coverage along the length of the estuary, including both banks;
- Sites with accessibility from the shore were preferred;
- Sites with infrastructure that was floating at low tide were preferred;
- Health and Safety considerations, e.g. avoidance of very soft mud.

It was agreed that, wherever possible the same sites should be resurveyed, to enable the closest comparison of the data. However, it was not possible to secure boat access within the restricted budget and timeframe, so in one case an alternative site was selected to provide coverage at a similar distance along the estuary; this was Riverside Railway Shore (site code RRP, replacing B5). Figure 2 is a map of the 14 sites surveyed in 2022, and an anonymised list of the sites is given at Appendix 1.



Figure 2: Map of the River Itchen showing the 2022 survey locations. Map imagery: Google Earth, © 2023.

## 2.2 Schedule

It was not possible to carry out the surveys at the same time of year as in 2017 (July). Following discussions with Natural England it was agreed to conduct the surveys between 3<sup>rd</sup> and 6<sup>th</sup> October 2022. The shore surveys were scheduled to take place at low tide.

## 2.3 Target species selection

The target list of NNS used in the wider Solent surveys in 2022 surveys (Bishop, Wood & Taylor, 2025) was used, see Appendix 2.

In this report all references to *Didemnum vexillum* should be interpreted as referring to either *Didemnum vexillum* or *Didemnum pseudovexillum* or both (Turon and others, 2020), as it was not possible to distinguish the two species within the timescale of this project.

## 2.4 Survey protocols

The marina and boatyard surveys were carried out following the protocol described in [NE Joint Report JP042](#) (Taylor, Wood & Bishop, 2022). However, at sites with only a few pontoons, the duration of the survey was reduced accordingly.

The shore surveys were carried out following, wherever possible, the NE guidance document 'Protocol for Rapid Assessment Survey for Non-Native Species on English Shores' (Taylor, Wood & Bishop, 2021). However, most of the shore sites were very small, so only two surveyors were employed, and the survey time was reduced accordingly. The Sailing Club 1 site (STD) had a small floating pontoon as well as an adjacent shore.

## 2.5 Field team

The core field team was John Bishop and Christine Wood from the MBA for all sites; and additionally Jessica Taylor from Natural England at the marina sites.

## 2.6 Health and safety

A generic risk assessment was carried out prior to the survey work, and safe working practices were drawn up. A dynamic risk assessment was then carried out on site prior to commencing survey work to identify any site-specific risks.

Primary health and safety concerns related to:

- Trip hazards in the marinas and boatyards, potentially resulting in a fall into deep water.
- Unsafe infrastructure on privately owned sites.
- Operating across areas of fine sediment on the shores.
- Becoming trapped by incoming tides.

All staff wore appropriate Personal Protective Equipment (PPE) for survey work, including buoyancy aids 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

## 2.7 Access permissions

Access permissions from relevant marina and boatyard operators, and landowners were obtained by the MBA prior to commencing the surveys.

## 2.8 Data analysis

### 2.8.1 Salinity

The salinity zones referred to in this report are based on the Venice classification (D'Ancona, 1959), which is the most common and accepted salinity classification scheme. Estuaries and their biota are often characterised by their salinity gradient, with species tending to inhabit particular portions of this gradient because of their innate salinity tolerances or the intersection of the salinity range with other necessary ecological features e.g. habitat or food supply (Guenther & MacDonald, 2012). The Venice scheme makes it possible to recognise and cross-reference equivalent salinity zones and their potential biota within different estuaries. We have further subdivided these zones, see Table 1.

**Table 1. Salinity zone classifications used in this report.**

Venice classification	Salinity (psu)	Subdivisions	Salinity (psu)
Oligohaline	0 - 5	Oligohaline	0 - 5
Mesohaline	5 - 18	Lower mesohaline	5 - 12
		Upper mesohaline	12 - 18
Polyhaline	18 - 30	Lower polyhaline	18 - 22
		Mid polyhaline	22 - 26
		Upper polyhaline	26 - 30
Euhaline	30 - 40	Euhaline	30 - 40

### 2.8.2 Statistics

The survey sites were each accorded a numerical value for purposes of characterising species' distributions in the estuary. From the tidal limit at Woodmill to the mouth, these site values were 1, 2, 3, 4, 5, 6, 7, 8, 8, 9, 10, 11, 11 and 12, the repetitions being for two pairs of sites on opposite sides of the estuary at equal distances from the tidal limit (see Figure 2). The centre of a species' distribution was calculated as the abundance-weighted arithmetic mean of the sites occupied, with extreme values of 1.0 and 12.0 for species recorded at only the most upstream and downstream site, respectively.

Paired T-tests were conducted in Excel, and multivariate analyses (MDS, CLUSTER, SIMPROF and RELATE) were conducted in PRIMER 6.

## 3 Results

All surveys were completed successfully.

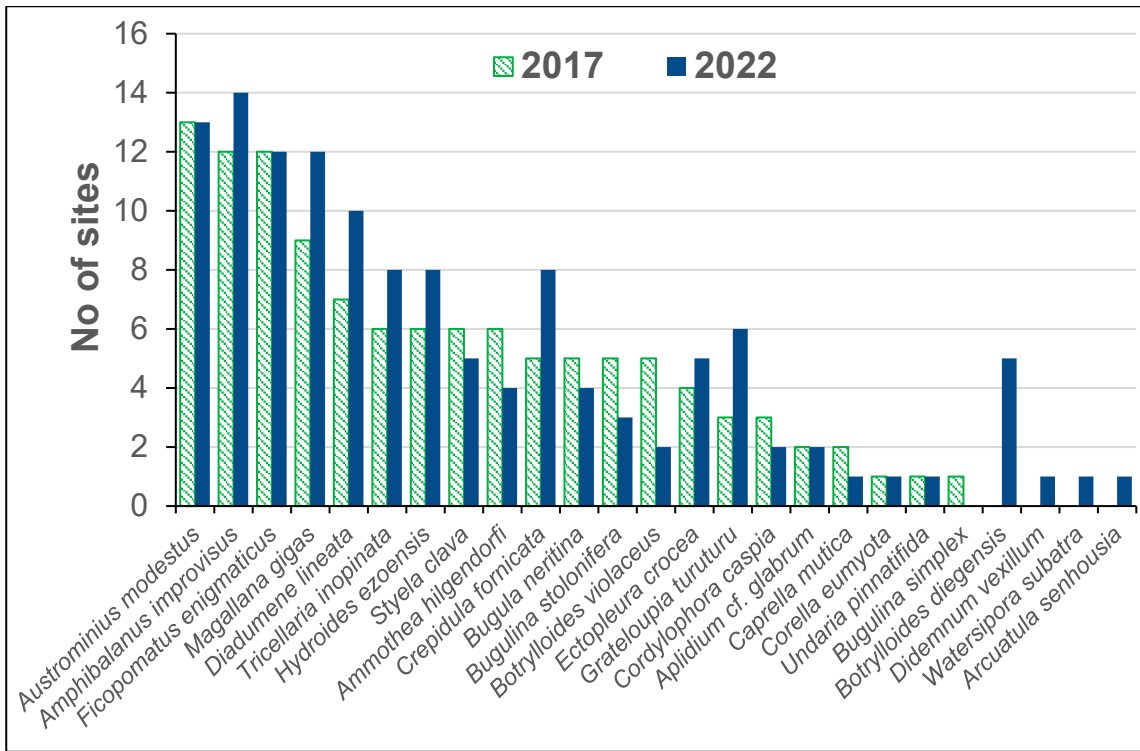
The detailed NNS occurrence data for 2022 and for the previous surveys in 2017 is provided at Appendices 4 and 5. The environmental measurements of salinity, temperature and turbidity collected at each marina, and environmental conditions noted for each shore site, are reported in Appendix 3. All NNS records were entered into Marine Recorder which will then automatically be uploaded to the NBN Atlas. The survey metadata was entered into MEDIN.

### 3.1 Basic survey data

In 2022, 129 NNS-occurrence records were noted, compared to 114 in 2017.

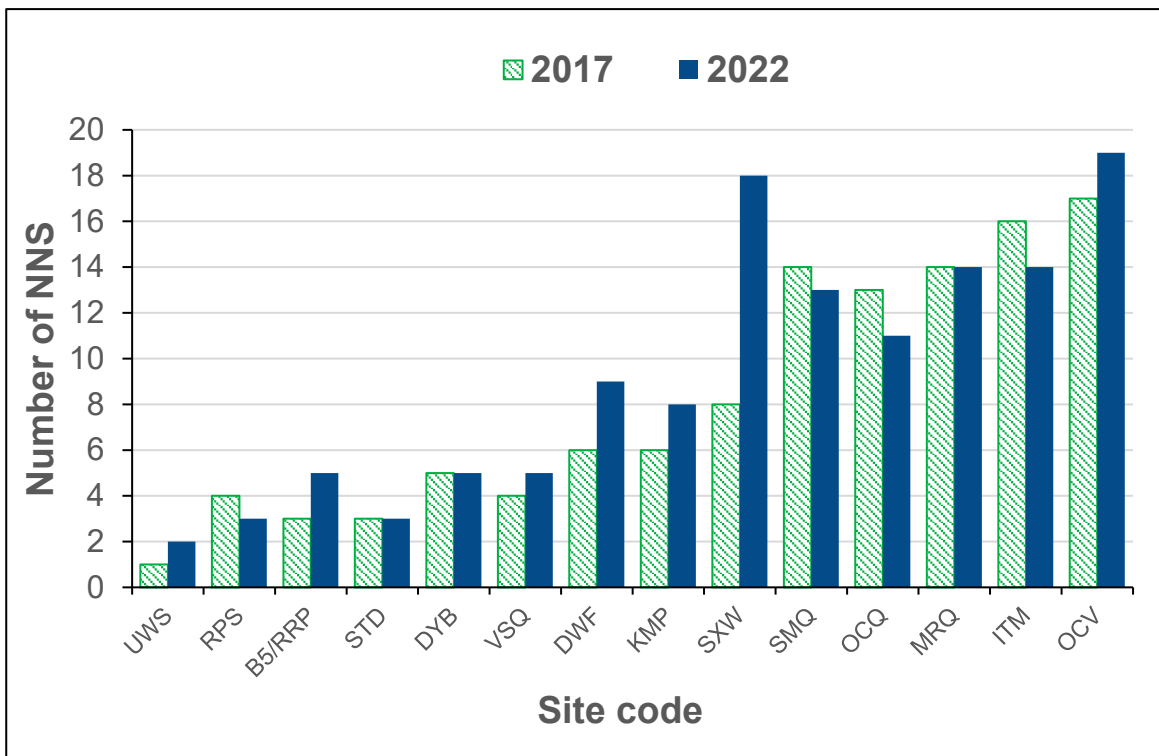
In 2022, 24 different NNS were recorded during the surveys, compared to 21 in 2017. The additional species found were *Watersipora subatra* (Red-ripple bryozoan) at a single site, *Arcuatula senhousia* (Asian date mussel) at a single site, *Didemnum vexillum* (Carpet sea squirt) at a single site and *Botrylloides diegensis* (San Diego sea squirt) at five sites. *Bugulina simplex* (a bryozoan) was recorded in 2017 but not in 2022.

The NNS most frequently found in 2022 were: *Amphibalanus improvisus* (Bay barnacle), *Austrominius modestus* (Darwin's barnacle), *Ficopomatus enigmaticus* (Trumpet tube-worm), *Magallana gigas* (Pacific oyster) and *Diadumene lineata* (Orange-striped anemone); these were all recorded at a minimum of 7 of the 14 sites on both occasions, see Figure 3. There was no significant difference between the 2017 and 2022 surveys in the mean number of sites occupied by an NNS (Paired T-test,  $P = 0.352$  for the 20 species found in both surveys;  $P = 0.135$  including the five additional species recorded in only one of the surveys).



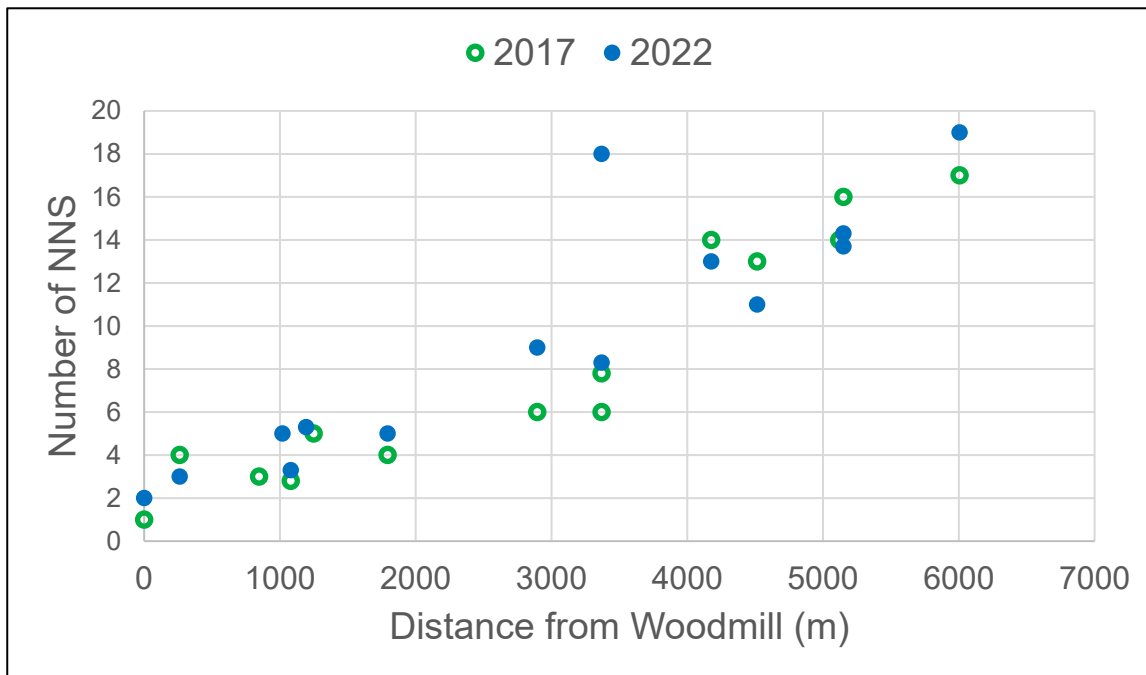
**Figure 3: Ranked bar chart of numbers of sites occupied by each NNS in 2017 and 2022.**

The maximum number of NNS found at any of the 15 sites surveyed in 2022 was 19 at OCV at the mouth of the R. Itchen, two more than the same site in 2017, see Figure 4. The mean number of NNS recorded per site was 8.1 in 2017 and 9.2 in 2022, but this difference was not significant (Paired T-test,  $P = 0.204$ ).



**Figure 4: Bar chart of the numbers of NNS recorded at each site in 2017 and 2022.**

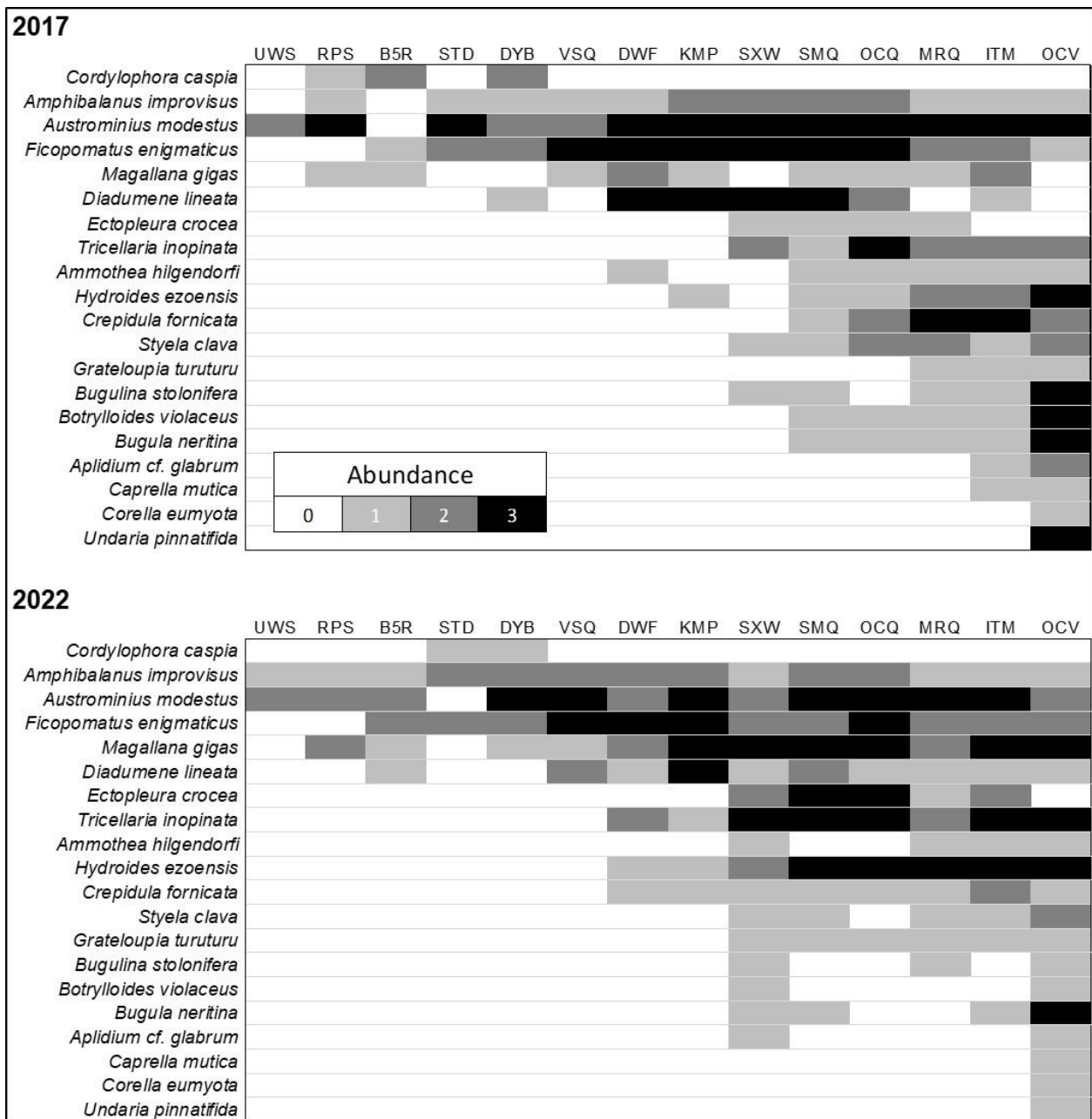
The number of NNS per site increases from the tidal limit at Woodmill to the mouth of the R. Itchen, see Figure 5. Note the dramatic rise in the number of NNS recorded at Marina 2 (site code SXW) as shown in Figure 4.



**Figure 5: Bivariate plots for the two surveys of numbers of NNS recorded at sites with increasing distance from the tidal limit at Woodmill.**

### 3.2 Species distributions within the estuary

Figure 6 allows comparison of the distribution of NNS, including estimated abundances, in the two surveys. Although this reveals very similar overall trends in the succession of species along the estuarine gradient, there are many cell-by-cell differences upon close inspection. Of the 129 species/site combinations recorded in 2022, 34 were for new species/site combinations not recorded in 2017, and there were 19 not recorded that had occurred in 2017, the majority of these changes were for species with Rare/occasional abundances (44 of 53). Many of these are likely to be due to chance variations in recording. Nevertheless, there is a highly significant correlation ( $P < 0.001$ ) between the two separate Bray-Curtis resemblance matrices of the sites from the different surveys (each matrix summarising similarities between sites based on their respective NNS assemblages in the relevant survey), with a fairly large value of Spearman's correlation coefficient ( $Rho = 0.64$ ) (RELATE routine in PRIMER).



**Figure 6: Distributions of the 20 NNS recorded during the 2017 and 2022 surveys across the 14 sites surveyed (UWS to OCV), shaded according to recorded abundance. The species are listed in the rank order of their centres of distribution calculated from the combined data of the two surveys.**

The centres of distribution of the 20 species recorded in both surveys did not differ significantly overall between 2017 and 2022 (Paired T-test,  $P = 0.105$ ) (see Table 2). Four individual species, *Amphibalanus improvisus*, *Crepidula fornicata* (Slipper limpet), *Grateloupia turuturu* (Devil's tongue weed) and *Aplidium cf. glabrum* (a colonial sea squirt), showed an apparent upstream movement of  $> 1.0$  in their centre of distribution from 2017 to 2022, while no species showed a downstream shift of  $> 1$ . *A. improvisus* appeared more prevalent in the upper estuary in 2022, and both *C. fornicata* and *G. turuturu* advanced three sites upstream in the middle estuary between surveys (see Figure 6). However, both *A. improvisus* and *C. fornicata* are 19th century introductions and seem extremely unlikely to be in the process of colonising the R. Itchen for the first time. *G.*

*turuturu* has been in the Solent area since at least 1969, was recorded at the mouth of the Itchen in 2004 (Arenas and others, 2006) and was very common throughout the Solent during MBA surveys in 2014, so again the species seems unlikely to have been newly colonising the Itchen between 2017 and 2022. *Aplidium* cf. *glabrum* has a very limited presence in the estuary and the relatively large numerical shift in its centre of distribution relates to just one loss and one gain of a site (see Figure 6), which could easily have arisen from random variation between recording events. In addition, this species closely resembles the native *Aplidium glabrum*, but so far lacks a definite taxonomic identification, this confusion has contributed to the species being very patchily documented.

Summer 2022 was exceptionally hot and dry, and flow levels in the River Itchen were lower than normal during the period June-August (Centre for Ecology and Hydrography, 2022). Some species may have moved further up the estuary in response to reduced freshwater flow. However, the species discussed above are all sessile as adults, so that any spatial extension in response to changing environmental conditions would inevitably incur the delays involved in completing a reproductive cycle.

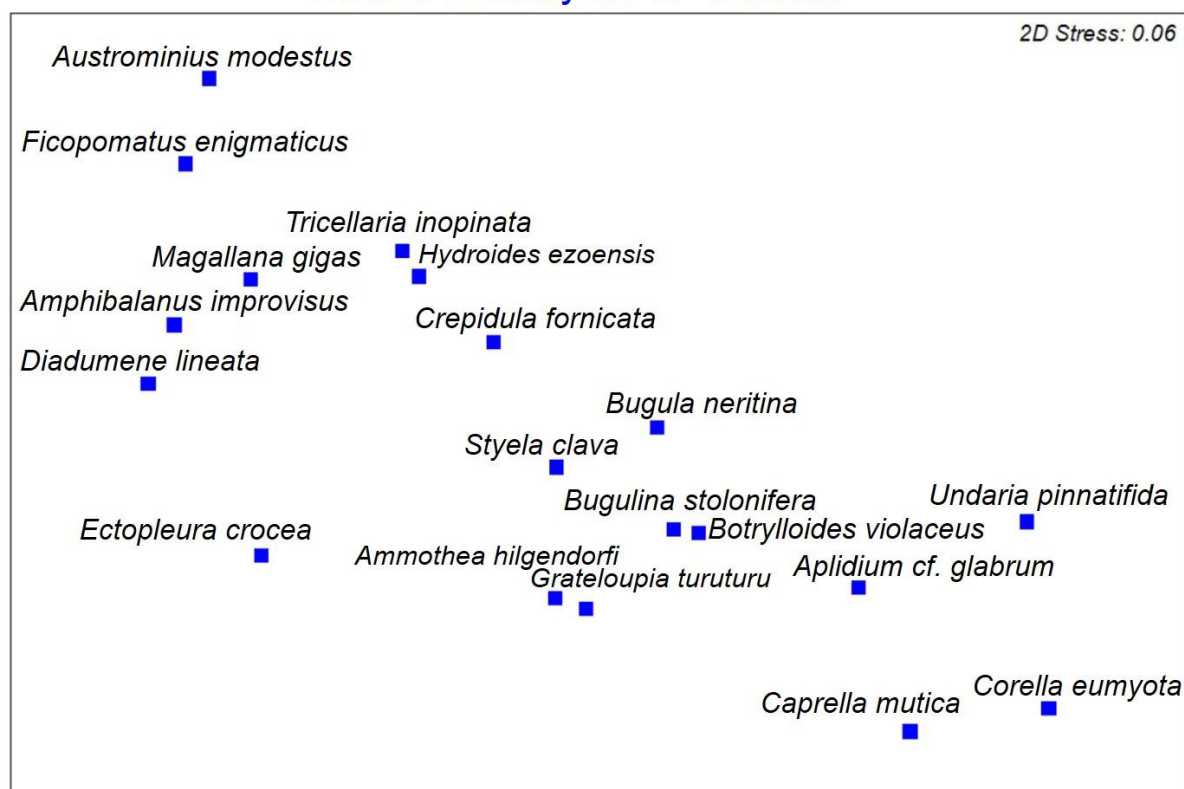
**Table 2. Centres of distribution of 20 species in the two surveys.**

Survey	2017	2022
<i>Aplidium</i> cf. <i>glabrum</i>	11.67	10.00
<i>Botrylloides violaceus</i>	11.00	10.00
<i>Corella eumyota</i>	12.00	12.00
<i>Styela clava</i>	10.44	10.50
<i>Bugula neritina</i>	11.00	10.67
<i>Bugulina stolonifera</i>	10.71	10.33
<i>Tricellaria inopinata</i>	10.25	9.70
<i>Diadumene lineata</i>	8.25	8.29
<i>Cordylophora caspia</i>	3.60	4.50
<i>Ectopleura crocea</i>	9.50	9.64
<i>Crepidula fornicata</i>	10.82	9.67
<i>Magallana gigas</i>	7.73	8.44
<i>Ficopomatus enigmaticus</i>	7.89	7.82
<i>Hydroides ezoensis</i>	10.70	10.00
<i>Ammothea hilgendorfi</i>	10.00	10.50
<i>Amphibalanus improvisus</i>	8.00	6.95
<i>Austrominius modestus</i>	7.50	7.45
<i>Caprella mutica</i>	11.50	12.00
<i>Grateloupia turuturu</i>	11.33	10.17
<i>Undaria pinnatifida</i>	12.00	12.00

### 3.3 Overview of combined data from 2017 and 2022

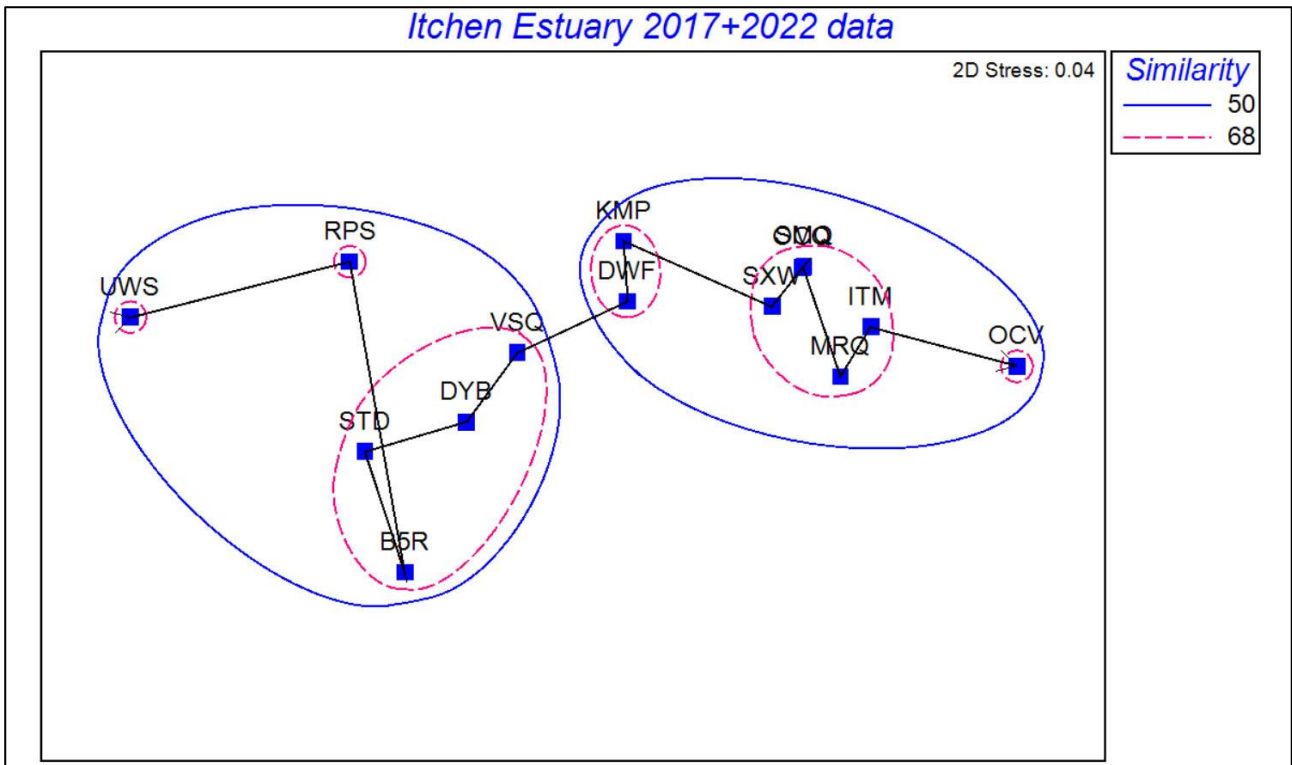
The MDS plot of NNS based on combined data (including abundance) from the two surveys shown in Figure 7 largely reflects the succession of species along the estuary, but it is notable that there are few or no clearly separate multi-species clusters of species. A Group-average dendrogram of the species from the combined data confirmed the absence of statistically significant clusters except for three species pairs at > 80% similarity (CLUSTER and SIMPROF in PRIMER). These pairs are: *Caprella mutica* (Japanese skeleton shrimp) with *Corella eumyota* (Orange-tipped sea squirt); *Amphibalanus improvisus* with *Magallana gigas*; and *Austrominius modestus* with *Ficopomatus enigmaticus*.

#### Itchen estuary 2017 & 2022



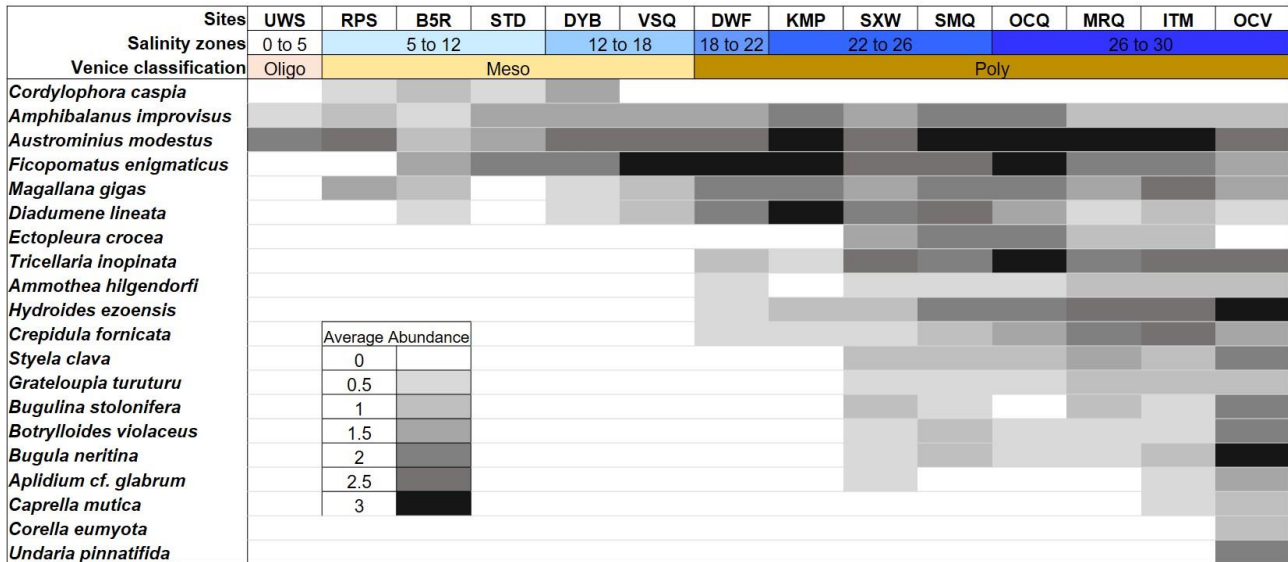
**Figure 7: MDS plot (PRIMER) showing relationships between different NNS in the combined data from the 2017 and 2022 surveys (omitting the outlier *Cordylophora caspia*); species with similar patterns of distribution along the estuary are shown close together.**

Group-average cluster analysis of the combined 2017 and 2022 NNS data (including abundance) indicates a major division, involving all sites, between DWF and VSQ, upstream and downstream of Northam (A3024) road bridge. Divisions at higher levels of similarity within the two major clusters separate groupings congruous with the spatial order of the sites: B5R, STD, DYB plus VSQ upstream of the Northam road bridge and DWF plus KMP downstream followed by SXW, SMQ, OQC, MRQ and ITM, leaving three ungrouped sites from the extreme ends of the salinity gradient (UWS, RPS and OCV), see Figure 8.



**Figure 8: MDS ordination of the Itchen survey sites based on combined data from the 2017 and 2022 surveys. Black line joins sites in their order along the estuary (note that SXW and KMP are on opposite banks of the estuary at an equal distance along it, as are MRQ and ITM, so the order of linkage within each pair is arbitrary). Ovals distinguish statistically significant clusters at the indicated similarity levels.**

The combined NNS occurrence data from the 2017 and 2022 surveys (see Figure 9) gives the best available overall summary of the species' distributions. The estimated salinity zones (based on Shi, 2000) and major divisions of the Venice System are also shown (see Section 2.8.1). A rapid decline in the number of NNS is seen between sites SXW and VSQ.



**Figure 9: Distributions of the 20 NNS recorded during both the 2017 and 2022 surveys across the 14 sites surveyed (UWS to OCV), shaded according to recorded abundance. The results of the two surveys were averaged for each cell. The species are listed in the rank order of their centres of distribution calculated from the combined data.**

## 3.4 Species of interest

### 3.4.1 *Watersipora subatra* (Red-ripple bryozoan)

This red encrusting bryozoan was first recorded in a Plymouth marina in 2008 (Ryland and others, 2009), since then it has spread along the South coast and to scattered localities on the west coast, becoming particularly common on natural shores in the southwest and beyond. It is tolerant to copper-based antifoulants.

See Section 4.2 for a detailed account of *Watersipora subatra* in the R. Itchen.



Figure 10: *Watersipora subatra*. Image: © J Bishop, MBA.

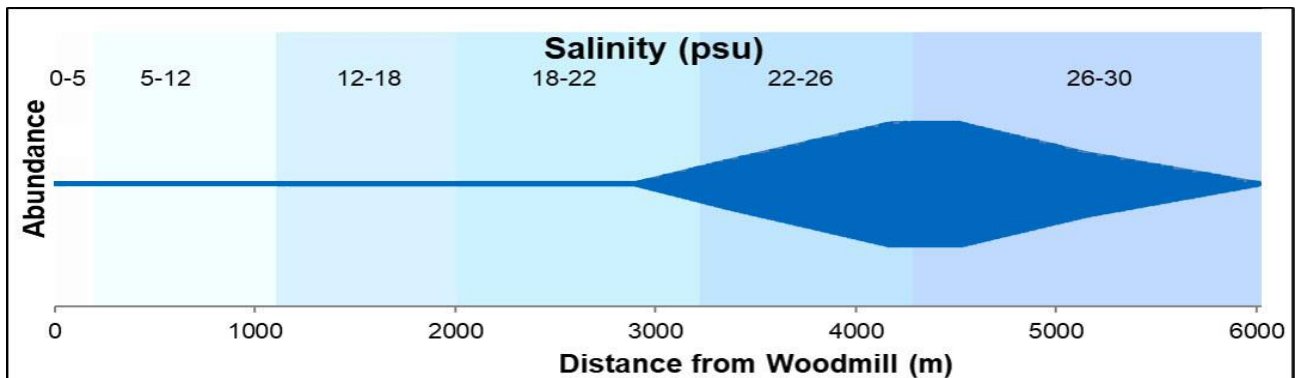
### 3.4.2 *Ectopleura crocea* (Pink-hearted hydroid)

This hydroid species has been very occasionally reported in the UK since 1895 with records from Plymouth and the R. Orwell (Rees, 1963), and more recently, in 2017, from the R. Itchen, see Appendix 5. However, it was not found in any of the 42 sites surveyed in the wider Solent in 2018/19 (Taylor, Wood & Bishop, 2022). In this study in 2022, *E. crocea* was found to be Abundant/superabundant at two sites, Frequent/common at two sites, and Rare/occasional at another site, see Appendix 4. It is possible that the timing of these 2022 surveys, in October, may have coincided with a peak in colony size; in 2017 it was found at four of the same sites as in 2022, but only as Rare/occasional.

Figure 11 illustrates its distribution along the estuarine gradient, with its abundance peaking in the lower part of the estuary in the mid to upper regions of the polyhaline zone, and its absence from the lower salinity zones. It was potentially mixed with the native *E.*

*larynx*, and, despite apparent colour differences between the two species in the field, confirmation of identification requires microscopical examination of the reproductive parts.

Hydroids are major biofouling organisms in global aquaculture. In Australia, *E. crocea* was found to impact commercial mussel culture firstly at spatfall, through consumption of larvae, and also during growth resulting in reduced length and weight of mussels (Fitridge & Keogh, 2013).



**Figure 11: *Ectopleura crocea*. Kite diagram illustrating distribution along estuarine gradient in the R. Itchen from 2017 and 2022 data combined.**



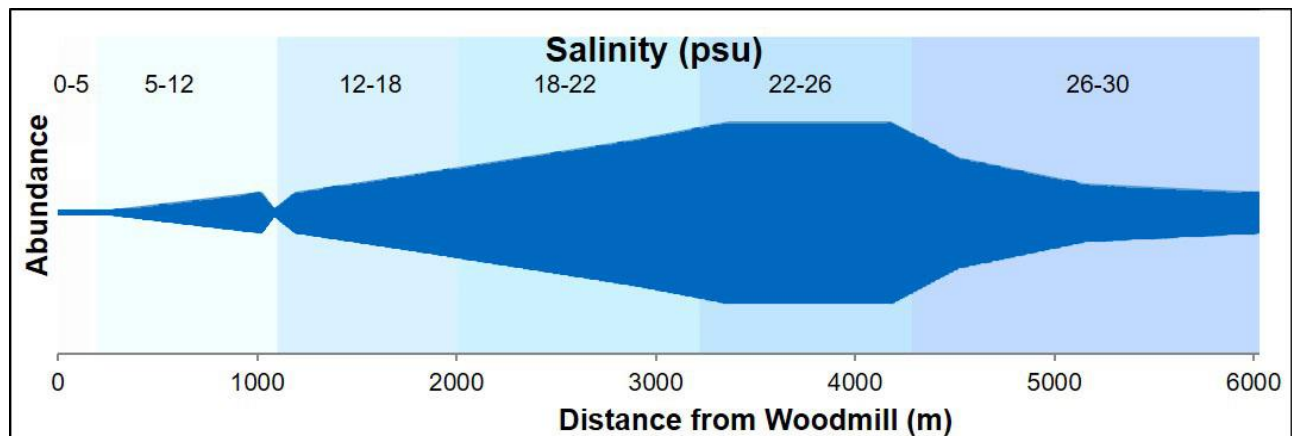
**Figure 12: *Ectopleura crocea* on a fender in the R Itchen (Image: © C Wood, MBA) and in close-up underwater (Image: © J Bishop, MBA).**

### **3.4.3 *Diadumene lineata* (Orange-striped anemone)**

*Diadumene lineata* is believed to be the world's most widely distributed sea anemone. Native to the NW Pacific, it is now established on almost every temperate and tropical coast worldwide. In the UK, it has been recorded all along the south coast of England, around the Welsh coast, and from a few sites in N. Ireland and Scotland. In these areas, it is typically found in sheltered estuaries attached to artificial structures in marinas and harbours, often in association with oysters and mussels, but also on sheltered natural

shores, on stones, shells and seaweeds. Under suitable conditions, it can quickly form large clonal aggregations by fission (GBNNSIP, 2023a). It can survive for months in salinities as low as 10 psu (Miyawaki, 1952), although growth and fission are reduced below 24 psu (Podbielski and others, 2016).

One of the largest populations of this species in the UK can be found in the middle section of the Itchen Estuary. Figure 13 illustrates that, although present throughout virtually the whole length of the estuary (excluding only the oligohaline zone near the tidal limit), its abundance peaks in the mid polyhaline zone.



**Figure 13: *Diadumene lineata*. Kite diagram illustrating distribution along estuarine gradient in the R. Itchen from 2017 and 2022 data combined.**

### **3.4.4 *Ficopomatus enigmaticus* (Trumpet tube-worm) and *Hydroides ezoensis* (Twin-keel worm)**

*Hydroides ezoensis* is thought to originate from Japan and is indigenous to the NW Pacific. It was first recorded in the UK from Southampton Water in 1976 (Thorp, Pyne and West, 1987).

The native range of *Ficopomatus enigmaticus* is unknown; it occurs in warm and temperate regions of both the Southern and Northern hemispheres. It can tolerate salinities from 1 to 55 psu but seems especially abundant in coastal brackish waters (Ten Hove and Weerdenburg, 1978). In the UK it was originally observed in London Docks in 1922 (Monro, 1924).

Both species possess calcified tubes that can form thick aggregations that can change the geomorphology of the local ecosystem by altering the hydrodynamic and sediment characteristics and provide complex habitat for benthic species. They may enhance water quality by removing particulate matter, although increased eutrophication has also been reported (GBNNSIP, 2023b; 2023c).

The calcareous tubes can be a serious fouling nuisance on ships, buoys and other harbour structures, and also block pipes in cooling systems. Significant economic losses may be incurred through cleaning costs and loss of utility. *F. enigmaticus* can be a

particular problem on recreational boat propellers, preventing rotation and leading to engine damage, see Figure 18.

Both of these species are fouling nuisances in the R. Itchen, with *H. ezoensis* dominating in the mid to upper regions of the polyhaline zone, but absent in the mesohaline and oligohaline zones, see Figure 15. In contrast, *F. enigmaticus* is present throughout most of the estuary (excluding only the oligohaline zone), and peaks predominantly in the lower and mid polyhaline, see Figure 14. They were also frequently found growing together in the same clump, although this only became apparent during laboratory analysis when clumps were dismantled to confirm identification.

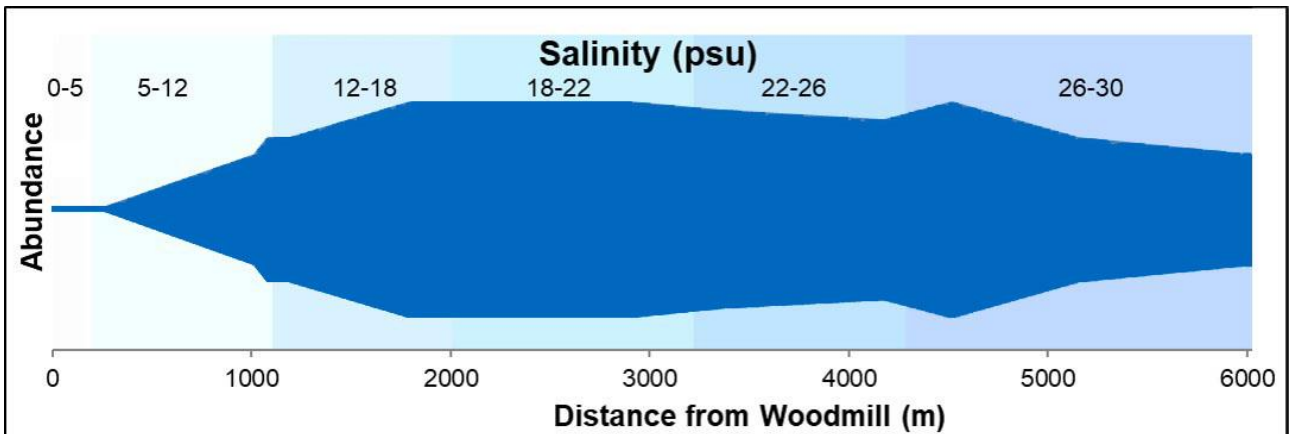


Figure 14: *Ficopomatus enigmaticus*. Kite diagram illustrating distribution along estuarine gradient in the R. Itchen from 2017 and 2022 data combined.

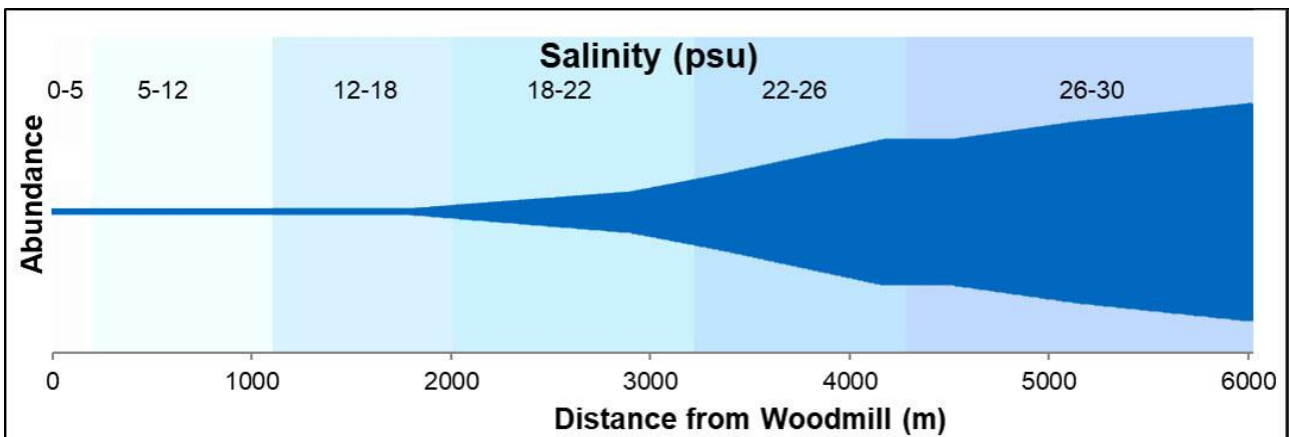


Figure 15: *Hydroides ezoensis*. Kite diagram illustrating distribution along estuarine gradient in the R. Itchen from 2017 and 2022 data combined.



Figure 16: *Hydroides ezoensis*. Image: © J Bishop, MBA.



Figure 17: *Ficopomatus enigmaticus*, large clump on a rope at Marina 2 site SXW). Image: © J Bishop, MBA.

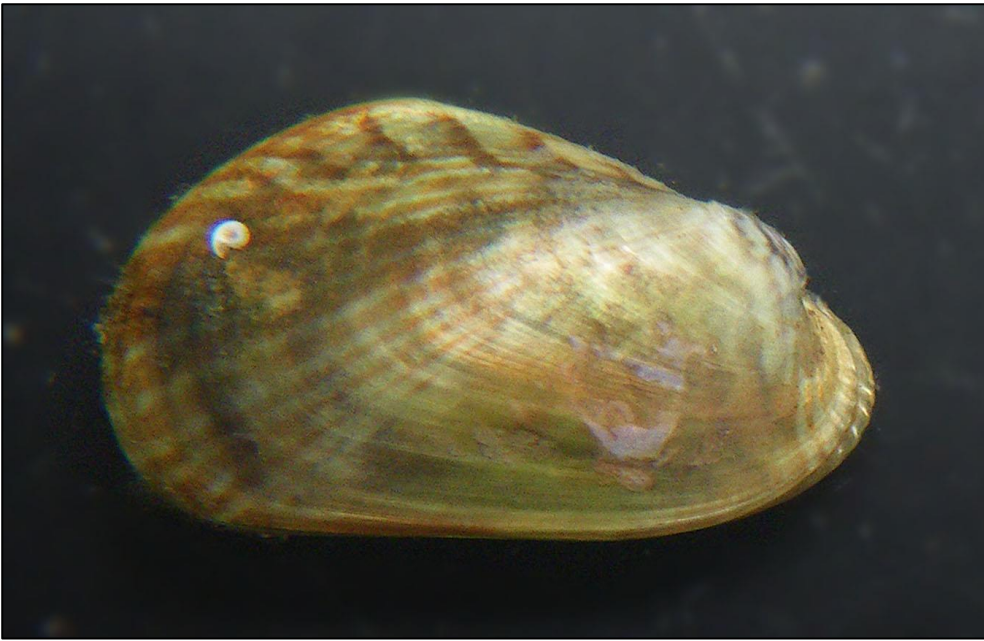


**Figure 18: *Ficopomatus enigmaticus* on hull of workboat in Southampton Water, berthed adjacent to Marina 3 (SMQ). Image: © Rob Holland.**

### **3.4.5 *Arcuatula senhousia* (Asian date mussel)**

*Arcuatula senhousia* was first recorded in the UK from Southampton Water in 2011 from Environment Agency benthic samples. Its distribution is currently restricted to the central part of the south coast, having only been reported from Hampshire and the Isle of Wight, but not outside the Solent. In 2018 and 2019 specimens were found at Weston shore in the R. Itchen and at the sites referred to in this report as Marina 2 (SXW) and Marina 3 (SMQ) (Watson and others, 2021). Although during these 2022 surveys it was not found at those particular marinas, a few juveniles were noted at the dry stack pontoon (DWF).

Large aggregations of *A. senhousia* can dramatically alter the ecology of soft shores. The intertwined byssal mats stabilise the sediments creating firm substrate, altering the hydrodynamics, sediment structure, nutrient cycling and animal behaviour. Seagrass beds can be negatively impacted possibly due to toxins in the sediment. *A. senhousia* may also compete for space and food with other bivalves, but can provide a new food source for a variety of predators such as shorebirds. There can also be a negative economic impact on bivalve shellfisheries e.g. clams (GBNNSIP, 2023d).



**Figure 19: *Arcuatula senhousia* from a marina in the R. Test. Image: © J Bishop, MBA.**

### **3.4.6 *Botrylloides diegensis* (San Diego sea squirt) and *Botrylloides violaceus* (Orange cloak sea squirt)**

*Botrylloides diegensis* was not found during the 2017 surveys, but in 2022 it occupied 5 sites in the R. Itchen. Conversely *B. violaceus* was found at 5 sites in 2017 and only at two in 2022. This apparent replacement was also seen in the 2018/19 and 2022 surveys of sites in the wider Solent (Bishop, Wood & Taylor, 2025). The reason for this is not known and requires further investigation. A study in Bodega Bay, California, determined that growth rate and competitive ability for both species were affected by temperature, salinity, and chlorophyll-a level (an indicator of phytoplankton availability) (Gul, 2015). For *B. diegensis* growth rate was highest at 18.5°C and lowest at 16.9°C, whereas for *B. violaceus* growth rate was highest at 16.4°C and lowest at 19.5°C, thus it is possible that the hot summer in 2022 favoured the growth of *B. diegensis*. The study also found that both species were negatively affected by reduced salinity, although this was possibly more pronounced in *B. violaceus*. Competition for space between the species is another possible explanation of the shift in abundance between the two species. Edwards & Stachowicz (2010) report that *B. diegensis* and *B. violaceus* have very similar life history traits such as growth, fecundity, mortality and overgrowth ability, but have statistically distinct seasonal patterns of recruitment. They also found that when co-settled, *B. diegensis* was much more likely to overgrow *B. violaceus* than the other way around (with *B. diegensis* 'winning' in 50% of encounters, no winner in 45% and *B. violaceus* winning in 5% (interpretation of Figure D1, Edwards & Stachowicz, 2010)).

### 3.4.7 *Amphibalanus improvisus* (Bay barnacle) and *Austrominius modestus* (Darwin's barnacle)

These barnacles are of particular interest as they are the only NNS on the target list (see Section 2.3) found throughout the estuary, including within the oligohaline zone near the tidal limit, at Woodmill. Figure 20 illustrates the even distribution of *A. improvisus* throughout much of the estuary, with abundance only falling off somewhat in the mesohaline and upper polyhaline zones.

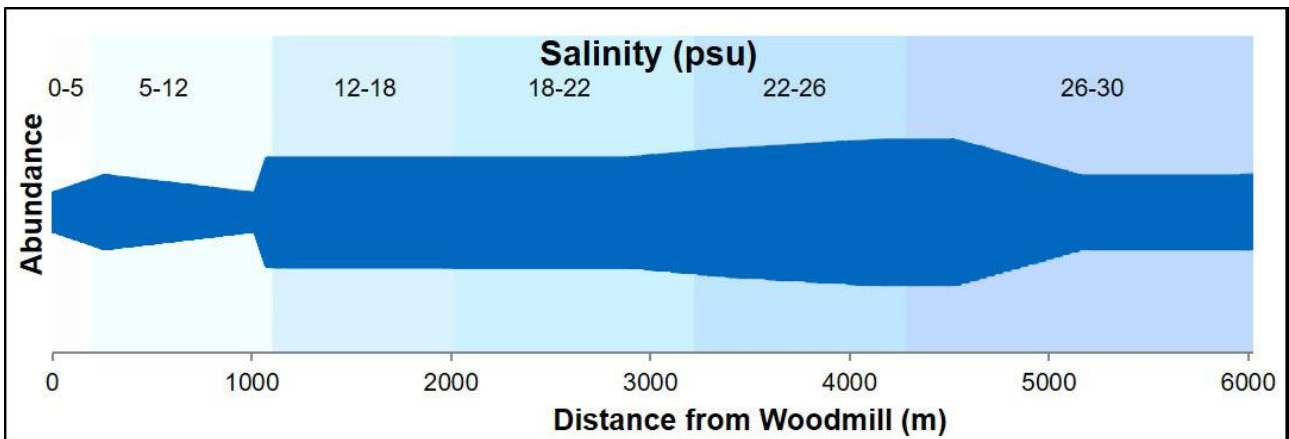


Figure 20: *Amphibalanus improvisus*. Kite diagram illustrating distribution along estuarine gradient in the R. Itchen from 2017 and 2022 data combined.

### 3.4.8 Other species of interest

Three species, *Caprella mutica* (Japanese skeleton shrimp), *Corella eumyota* (Orange-tipped sea squirt), and *Undaria pinnatifida* (Wakame), were only recorded near the mouth of the estuary, in the upper polyhaline zone. Figure 21 illustrates their typical distribution pattern.

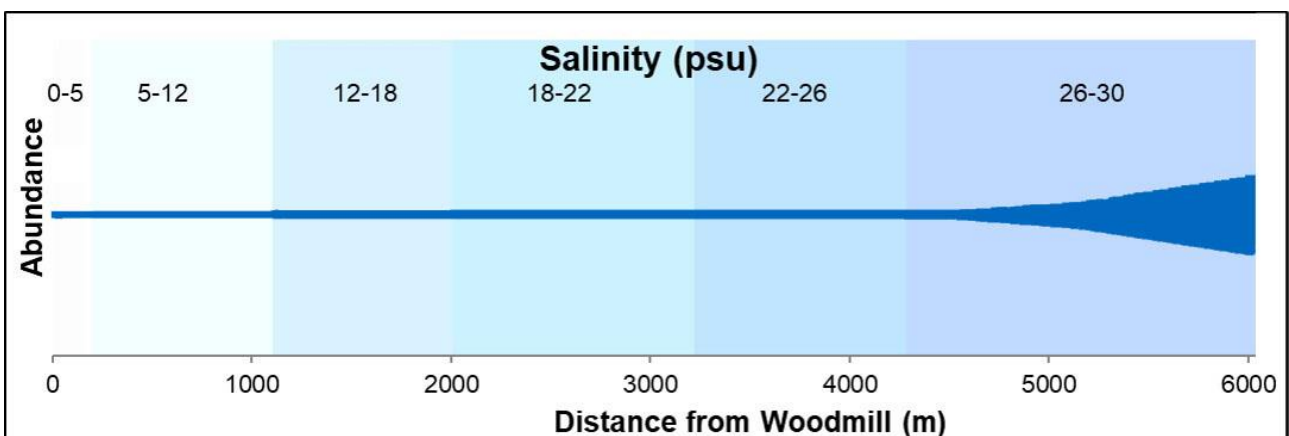


Figure 21: *Caprella mutica*. Kite diagram illustrating distribution along estuarine gradient in the R. Itchen from 2017 and 2022 data combined.

## 3.5 Sites of interest

### 3.5.1 Marina 2, site code SXW

A very marked increase in the number of NNS was noted between 2017 and 2022 at site SXW (see Figure 4): eight NNS were recorded in 2017, but 18 in 2022. It is possible that the species list recorded in 2017 was slightly reduced for some reason, in that two species that were recorded both upstream and downstream of SXW, *Magallana gigas* and *Ammothea hilgendorfi*, were unrecorded there, while *Hydroides ezoensis* was recorded on the opposite bank at KMP (see Figure 6). All three species were added at SXW in 2022. Beyond that, in 2022 SXW had gained five species that had only been recorded downstream of the site in 2017: *Crepidula fornicata*, *Grateloupia turuturu* (representing an upstream advance of three sites), *Botrylloides violaceus*, *Bugula neritina* and *Aplidium cf. glabrum* (an upstream jump of four sites from the 2017 distribution). Finally, *Didemnum vexillum*, which had not been recorded at all in 2017, was recorded at SXW alone in 2022, and SXW was the furthest upstream of the five sites at which *Botrylloides diegensis* was added in 2022 (Appendix 4). SXW thus became the upper limit in the estuary for nine of the 18 NNS recorded at the site in 2022, which also included *Didemnum vexillum* at its only site.

These additions gave a total number of NNS in 2022 more typical of the mouth of the estuary than of the sites neighbouring SXW, an occurrence lying outside the pattern of the other sites surveyed. A similar apparent influx of NNS, albeit in a very different setting, was documented at the 'Far' shore of the Chichester Harbour cluster of the 'Mapping Invasive Non-Native Species in the Solent: An Update -2022' surveys also undertaken in autumn 2022 (Bishop, Wood & Taylor, 2025). In the Itchen example, it is possible to envisage transfer of species to the marina site on a heavily fouled boat or infrastructure such as repositioned pontoons, with subsequent persistence possibly assisted by a period of low freshwater flow.

## 4 Discussion

### 4.1 Distribution and prevalence of NNS

No statistically significant overall increase in the presence of NNS in the Itchen was detected between 2017 and 2022, either in terms of the number of NNS per site or the number of sites occupied per NNS. Similarly, there was no significant overall movement of the calculated centres of distribution of the 20 species that were recorded in both 2017 and 2022.

Despite these overall conclusions, a remarkable increase of 10 NNS was recorded between 2017 and 2022 at one particular mid-estuary site, SXW. This site thereby became the upstream limit of eight of the 18 species recorded there in 2022, with another species at its only site in the survey.

Cluster analysis of species revealed no significant major clusters of species based on their respective distributions along the estuary, suggesting the absence of discrete zonal assemblages of the NNS along the estuarine gradient. However, cluster analysis of sites based on their respective NNS assemblages divided the estuary into two distinct groups of sites that respectively occupied the estuary above and below the Northam (A3024) road bridge and were estimated to coincide with the mesohaline and polyhaline zones of the estuary in the Venice classification (see Section 2.8.1). A rapid reduction of NNS diversity from around 16 to the six remaining species in the mesohaline zone occurred moving upstream towards this boundary (Figure 9).

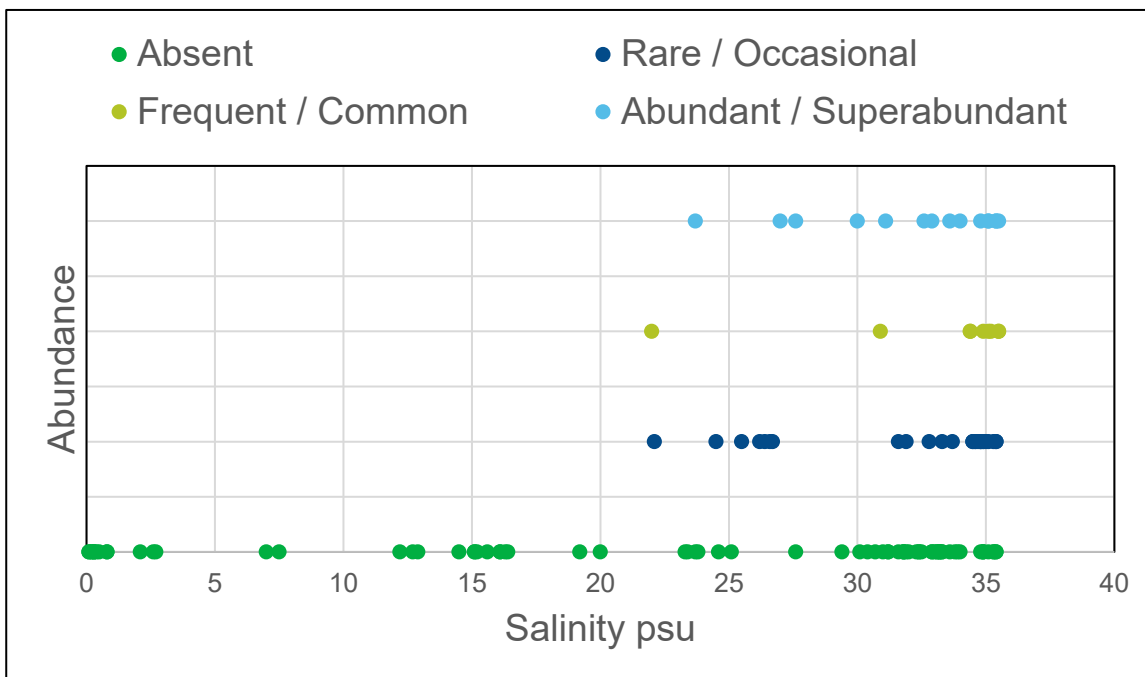
### 4.2 *Watersipora subatra* (Red-ripple bryozoan)

In 2017, *W. subatra* was not recorded in the R. Itchen, although it was found at 11 sites in the nearby R. Hamble (J. Bishop & C. Wood unpublished data, 2017). Then in 2018/19 it was recorded at the mouth of the R. Itchen at the site referred to in this report as Marina 5 (site code OCV) and was found to be widespread in the wider Solent area (Taylor, Wood & Bishop, 2022). Part of the motivation for the survey five years on from the 2017 study was to ascertain if *W. subatra*, a species of concern in the Solent region, is spreading into the Itchen.

In the 2022 survey, a single colony was found at Marina 3 (site code SMQ), midway up the estuary. However, *W. subatra* was not recorded at Marina 5 (OCV), where it had been noted as rare in 2019 (see Appendix 4). Thus, it appears that *W. subatra* had not spread significantly into the R. Itchen since 2017.

Cohen (2011) describes a salinity range for *W. subatra* in California of 25 – 37 psu. Analysis of data from 128 RASs carried out by J. Bishop and C. Wood within the known UK range of *W. subatra* indicates that it has a lower salinity tolerance of approximately 22 psu in southern UK, see Figure 22. It is typically recorded near the water surface either on floating substrates, or in the lower intertidal zone on shores, where it is exposed at low

tide. Thus, taking into account the surface salinity regime in the R. Itchen, see Figure 1, it appears likely that *W. subatra* could spread up the R. Itchen almost as far as Northam Bridge i.e. just above the dry stack pontoon (DWF) and Marina 2 (SXW), approximately 3 km below Woodmill. This is in sharp contrast to the nearby R. Hamble where *W. subatra* has been detected as far up as a pontoon at Fairthorne Manor just over 1 km below the tidal limit at Botley (J. Bishop & C. Wood unpublished data, 2017). The most likely explanation for this difference is that the R. Hamble has a much lower riverine freshwater input, see Table 3, thus salinities will remain higher upriver. Nevertheless, this analysis does suggest that *W. subatra* should be able to colonise several sites within the lower region of the estuary, and its continuing near-absence in the polyhaline sector of the estuary is not fully explained.



**Figure 22: Scatter plot of *W. subatra* abundance and surface salinity at site at time of observation during surveys other than those reported here.**

**Table 3. River flows. Data collected by the Environment Agency (Townsend, 2008).**

Flow Rates (m <sup>3</sup> sec <sup>-1</sup> )	Typical range	Mean winter
R. Itchen	3 - 13	11.9
R. Hamble	0.6	1.3

### 4.3 Limitations and recommendations

Despite substantial broad similarities, numerous minor differences existed between the 2017 and 2022 data sets. The replacement of a site accessed by boat in 2017 by an onshore site in 2022 (B5/RRP) may have contributed to differences in the NNS recorded and respective abundances recorded there.

A broader consideration is that the 2017 surveys were carried out in July whereas the 2022 surveys were conducted in October, so seasonal differences could have reduced the comparability of the data sets. Some species, particularly the seaweeds, are highly seasonal, although most species are readily visible by July, and winter die-back is generally most apparent from November onwards. However, the strong reduction in abundance recorded for *Undaria pinnatifida* at the mouth of the estuary is very likely to reflect the strong late-summer regression of the macroscopic (sporophyte) phase of this species following rapid spring growth.

Perhaps most importantly, a large proportion of records are of species at relatively low abundance and many of the sites visited on the Itchen are of limited extent, so there is great potential for chance variation in whether or not a species is recorded at a site on a given occasion. This probably accounts for many of the discontinuous distributions seen for both years in Figure 6.

Re-survey of the Itchen confirmed the general pattern of succession of NNS in the estuary and added four NNS to the list. The failure of *Watersipora subatra* to encroach further on the estuary over a period of five years was documented, and a remarkable increase in NNS at one site was detected. The MBA has unpublished data of NNS surveys in a number of other estuaries (Hamble, Dart, Teign, Tamar, Plym, Yealm, and Fal) from 2018 to 2021. Consideration should be given to whether repeat surveys could provide useful information to aid understanding of patterns and processes of colonisation of these important sites.

Adequate knowledge of the salinity regime enables biological observations of NNS distribution in an estuary to be placed into a general framework, facilitating comparison of different water bodies and the description of common patterns, with the ultimate aim of making useful predictions of the risk from particular NNS at different positions along the estuarine gradient.

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# Appendices

## Appendix 1: Details of sites surveyed

Site code	Site	Latitude	Longitude	Distance from Woodmill (m)	Survey date
UWS	Watersports centre shore	50.934258	-1.380059	1	05/10/2022
RPS	Riverside Park shore	50.932262	-1.380274	263	05/10/2022
RRS	Riverside Railway shore	50.926024	-1.379030	1,020	05/10/2022
STD	Sailing club 1 shore	50.925135	-1.379502	1,081	05/10/2022
DYB	Boatyard 1	50.924143	-1.378978	1,194	05/10/2022
VSQ	Sailing club 2	50.919687	-1.382049	1,794	05/10/2022
DWF	Dry stack pontoon	50.913748	-1.384966	2,896	04/10/2022
KMP	Marina 1	50.914074	-1.377946	3,370	06/10/2022
SXW	Marina 2	50.912615	-1.378882	3,370	04/10/2022
SMQ	Marina 3	50.909481	-1.380228	4,177	04/10/2022
OCQ	Marina 4	50.908152	-1.384405	4,516	05/10/2022
MRQ	Boatyard 2	50.902206	-1.384703	5,151	04/10/2022
ITM	Boatyard 3	50.902120	-1.389192	5,151	04/10/2022
OCV	Marina 5	50.895336	-1.391457	6,007	03/10/2022

Notes: Sites listing in order from the tidal limit at Woodmill to where the Itchen meets the Test at Dock Head in Southampton Water. Distances from the tidal limit at Woodmill measured using Google Earth.

## Appendix 2: Non-native species target list

Informal group	Species	Informal group	Species
<b>Ascidians</b>	<i>Aplidium cf. glabrum</i>	<b>Annelid worms</b>	<i>Bispira polyomma</i>
	<i>Asterocarpa humilis</i>		<i>Ficopomatus enigmaticus</i>
	<i>Botrylloides violaceus</i>		<i>Hydroides dianthus</i>
	<i>Botrylloides diegensis</i>		<i>Hydroides elegans</i>
	<i>Ciona robusta</i>		<i>Hydroides ezoensis</i>
	<i>Corella eumyota</i>	<b>Arthropods</b>	<i>Ammothea hilgendorfi</i>
	<i>Didemnum vexillum</i>		<i>Amphibalanus amphitrite</i>
	<i>Perophora japonica</i>		<i>Amphibalanus improvisus</i>
	<i>Styela clava</i>		<i>Austrominius modestus</i>
	<i>Caprella mutica</i>		
<b>Bryozoans</b>	<i>Bugula neritina</i>		<i>Dyspanopeus sayi</i>
	<i>Bugulina fulva</i>		<i>Eriocheir sinensis</i>
	<i>Bugulina simplex</i>		<i>Hemigrapsus sanguineus</i>
	<i>Bugulina stolonifera</i>		<i>Hemigrapsus takanoi</i>
	<i>Schizoporella japonica</i>		<i>Hesperibalanus fallax</i>
	<i>Tricellaria inopinata</i>	<b>Brown algae</b>	<i>Colpomenia peregrina</i>
	<i>Watersipora subatra</i>		<i>Sargassum muticum</i>
	<i>Undaria pinnatifida</i>		
<b>Sponges</b>	<i>Celtodoryx ciocalyptoides</i>	<b>Red algae</b>	<i>Asparagopsis armata</i>
<b>Anemones</b>	<i>Diadumene lineata</i>		<i>Bonnemaisonia hamifera</i>
<b>Molluscs</b>	<i>Arcuatula senhousia</i>		<i>Caulacanthus okamurae</i>
	<i>Crepidula fornicata</i>		<i>Botryocladia wrightii</i>
	<i>Ensis leei</i>		<i>Gracilaria vermiculophylla</i>
	<i>Magallana gigas</i>		<i>Grateloupia turuturu</i>
	<i>Mercenaria mercenaria</i>		<i>Melanothamnus harveyi</i>
	<i>Ocinebrellus inornatus</i>		<i>Pikea californica</i>
	<i>Rapana venosa</i>	<i>Solieriaceae</i>	
	<i>Ruditapes philippinarum</i>		
<i>Urosalpinx cinerea</i>	<b>Green algae</b>	<i>Codium fragile fragile</i>	
<b>Hydroids</b>		<i>Ectopleura crocea</i>	<i>Umbraulva dangeardii</i>

### Appendix 3: Environmental survey data

Site Code	Survey Date	Pressure	Air temp. (°C)	Salinity Surface	Salinity 2m	Sea temp. (°C) Surface	Sea temp. 2m	Turbidity (Secchi depth) m
UWS	05/10/2022	1012	18	1.1		14.5		
RPS	05/10/2022	1012	17	1.1		14.5		
RRS	05/10/2022	1012	17	2.5		15.1		
STD	05/10/2022	1010	17	2.1	26.7	14.5	16.4	
DYB	05/10/2022	1012	16	2.6	28.1	14.8	16.4	2.0
VSQ	05/10/2022	1010	17	7.5	28.5	15.1	16.4	
DWF	04/10/2022	1017	17	15.5	30.6	15.7	16.5	3.0
KMP	06/10/2022	1027	12	13.3	31.9	13.5	16.5	2.3
SXW	04/10/2022	1017	16	15.3	30.0	15.5	16.4	2.6
SMQ	04/10/2022	1018	16	18.0	30.2	15.6	16.4	2.4
OCQ	05/10/2022	1010	19	18.8	29.3	15.9	16.5	2.0
MRQ	04/10/2022	1017	17	27.8	28.9	16.5	16.6	1.4
ITM	04/10/2022	1018	16	26.9	32.6	16.3	16.6	2.8
OCV	03/10/2022	1025	17	28.6	32.6	16.2	16.5	

Notes: Sea temperature, salinity and turbidity from personal observation using YSI 30 Salinometer and Secchi disk. Pressure and air temperature from [www.timeanddate.com/weather/uk](http://www.timeanddate.com/weather/uk)

## Appendix 4: 2022 NNS occurrences and abundances

2022	UWS	RPS	RRS	STD	DYB	VSQ	DWF	KMP	SXW	SMQ	OCQ	MRQ	ITM	OCV
<i>Aplidium cf. glabrum</i>									R					R
<i>Asterocarpa humilis</i>														
<i>Botrylloides diegensis</i>									R		R	R	R	F
<i>Botrylloides violaceus</i>									R					R
<i>Ciona robusta</i>														
<i>Corella eumyota</i>														R
<i>Didemnum vexillum</i>									R					
<i>Perophora japonica</i>														
<i>Styela clava</i>									R	R		R	R	F
<i>Bugula neritina</i>									R	R			R	A
<i>Bugulina fulva</i>														
<i>Bugulina simplex</i>														
<i>Bugulina stolonifera</i>									R		R			R
<i>Schizoporella japonica</i>														
<i>Tricellaria inopinata</i>							F	R	A	A	A	F	A	A
<i>Watersipora subatra</i>									R					
<i>Celtodoryx ciocalyptoides</i>														
<i>Cordylophora caspia</i>				R	R									
<i>Ectopleura crocea</i>									F	A	A	R	F	
<i>Diadumene lineata</i>			R			F	R	A	R	F	R	R	R	R
<i>Arcuatula senhousia</i>							R							
<i>Crepidula fornicata</i>							R	R	R	R	R	R	F	R
<i>Ensis leei</i>														
<i>Magallana gigas</i>		F	R		R	R	F	A	A	A	A	F	A	A
<i>Mercenaria mercenaria</i>														
<i>Ocenebrellus inornatus</i>														
<i>Rapana venosa</i>														
<i>Ruditapes philippinarum</i>														
<i>Urosalpinx cinerea</i>														
<i>Bispira polyomma</i>														
<i>Ficopomatus enigmaticus</i>			F	F	F	A	A	A	F	F	A	F	F	F
<i>Hydroides dianthus</i>														
<i>Hydroides elegans</i>														
<i>Hydroides ezoensis</i>							R	R	F	A	A	A	A	A
<i>Ammothoe hilgendorfi</i>									R			R	R	R
<i>Amphibalanus amphitrite</i>														
<i>Amphibalanus improvisus</i>	R	R	R	F	F	F	F	F	R	F	F	R	R	R
<i>Austrominius modestus</i>	F	F	F		A	A	F	A	F	A	A	A	A	F
<i>Caprella mutica</i>														R
<i>Dyspanopeus sayi</i>														
<i>Eriocheir sinensis</i>														
<i>Hemigrapsus sanguineus</i>														
<i>Hemigrapsus takanoi</i>														
<i>Hesperibalanus fallax</i>														
<i>Asparagopsis armata</i>														
<i>Bonnemaisonia hamifera</i>														
<i>Botryocladia wrightii</i>														
<i>Caulacanthus okamurae</i>														
<i>Codium fragile fragile</i>														
<i>Colpomenia peregrina</i>														
<i>Gracilaria vermiculophylla</i>														
<i>Grateloupia turuturu</i>									R	R	R	R	R	R
<i>Melanothamnus harveyi</i>														
<i>Pikea californica</i>														
<i>Sargassum muticum</i>														
<i>Solieriaceae</i>														
<i>Umbraulva dangeardii</i>														
<i>Undaria pinnatifida</i>														R

## Appendix 5: 2017 NNS occurrences and abundances

2017	UWS	RPS	B5	STD	DYB	VSQ	DWF	KMP	SXW	SMQ	OCQ	MRQ	ITM	OCV
<i>Aplidium cf. glabrum</i>													R	F
<i>Asterocarpa humilis</i>														
<i>Botrylloides diegensis</i>														
<i>Botrylloides violaceus</i>										R	R	R	R	A
<i>Ciona robusta</i>														
<i>Corella eumyota</i>														R
<i>Didemnum vexillum</i>														
<i>Perophora japonica</i>														
<i>Styela clava</i>									R	R	F	F	R	F
<i>Bugula neritina</i>										R	R	R	R	A
<i>Bugulina fulva</i>														
<i>Bugulina simplex</i>														F
<i>Bugulina stolonifera</i>									R	R		R	R	A
<i>Schizoporella japonica</i>														
<i>Tricellaria inopinata</i>									F	R	A	F	F	F
<i>Watersipora subatra</i>														
<i>Celtodoryx ciocalyptoides</i>														
<i>Cordylophora caspia</i>		R	F		F									
<i>Ectopleura crocea</i>									R	R	R	R		
<i>Diadumene lineata</i>					R		A	A	A	A	F		R	
<i>Arcuatula senhousia</i>														
<i>Crepidula fornicata</i>										R	F	A	A	F
<i>Ensis leei</i>														
<i>Magallana gigas</i>		R	R			R	F	R		R	R	R	F	
<i>Mercenaria mercenaria</i>														
<i>Ocinebrellus inornatus</i>														
<i>Rapana venosa</i>														
<i>Ruditapes philippinarum</i>														
<i>Urosalpinx cinerea</i>														
<i>Bispira polyomma</i>														
<i>Ficopomatus enigmaticus</i>			R	F	F	A	A	A	A	A	A	F	F	R
<i>Hydroides dianthus</i>														
<i>Hydroides elegans</i>														
<i>Hydroides ezoensis</i>								R		R	R	F	F	A
<i>Ammothea hilgendorfi</i>							R			R	R	R	R	R
<i>Amphibalanus amphitrite</i>														
<i>Amphibalanus improvisus</i>		R		R	R	R	R	F	F	F	F	R	R	R
<i>Austrominius modestus</i>	F	A		A	F	F	A	A	A	A	A	A	A	A
<i>Caprella mutica</i>													R	R
<i>Dyspanopeus sayi</i>														
<i>Eriocheir sinensis</i>														
<i>Hemigrapsus sanguineus</i>														
<i>Hemigrapsus takanoi</i>														
<i>Hesperibalanus fallax</i>														
<i>Asparagopsis armata</i>														
<i>Bonnemaisonia hamifera</i>														
<i>Botryocladia wrightii</i>														
<i>Caulacanthus okamurae</i>														
<i>Codium fragile fragile</i>														
<i>Colpomenia peregrina</i>														
<i>Gracilaria vermiculophylla</i>														
<i>Grateloupia turuturu</i>												R	R	R
<i>Melanothamnus harveyi</i>														
<i>Pikea californica</i>														
<i>Sargassum muticum</i>														
<i>Solieriaceae</i>														
<i>Umbraulva dangeardii</i>														
<i>Undaria pinnatifida</i>														A

