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Research Article

The status of non-native bryozoans on the north coast of Ireland

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Abstract

A list of thirty-seven non-indigenous species (NIS) or cryptogens likely to appear on marinas or pontoons were targeted during a ten-day survey in 2012 on the north Irish coast. This included four bryozoan species. The non-targeted cryptogen, *Bugulina fulva*, was found for the first time in the Republic of Ireland. The bryozoans *Bugula neritina* and *Watersipora subatra* were found within Northern Ireland for the first time. The survey demonstrated that a rapid approach to sampling marinas and pontoons provides new range records of species likely to occur elsewhere within the region.

Key words: marine, Bryozoa, fouling, marina, pontoon, *Bugula neritina*, *Bugulina fulva*, *Bugulina simplex*, *Tricellaria inopinata*, *Watersipora subatra*, *Schizoporella japonica*

Introduction

Marinas are convenient places to sample for immersed biota, as these can be sampled at any tidal state, and boardwalks provide for easy access. Immersed surfaces of pontoons provide novel habitats for colonisation by sessile biota, and include the supporting piles (Connell 2000, 2001). Over the last decade, within several world regions, marinas have been studied by taxonomic specialists (Pedersen et al. 2005; Cohen et al. 2005; Arenas et al. 2006; Buschbaum et al. 2011). Many impacting non-indigenous species (NIS) have been revealed following such studies, although the majority of NIS found would be of little interest to managers. The development of a target list of species (Ashton et al. 2006; Minchin 2007b) reduces sampling effort, and selects for impacting NIS or those that may be of some special interest. Marinas can be surveyed rapidly, and NIS of concern can be reported directly to management for an appropriate response. Hayes et al. (2002) compiled NIS target lists composed of pest NIS that could be transmitted with potential consequences for natural resources, based on the known impacts of NIS elsewhere, and the likelihood of their spread by known pathways and vectors.

Immersed pontoon surfaces provide relatively silt-free surfaces due to their orientation and wave wash, so enabling attachment by sessile biota. Marinas generally have sheltered environments, and those in exposed areas have protective breakwaters behind which propagules may be retained, which might otherwise be dispersed, to inoculate pontoon surfaces (Floerl and Inglis 2003). Berthed craft alongside pontoons,

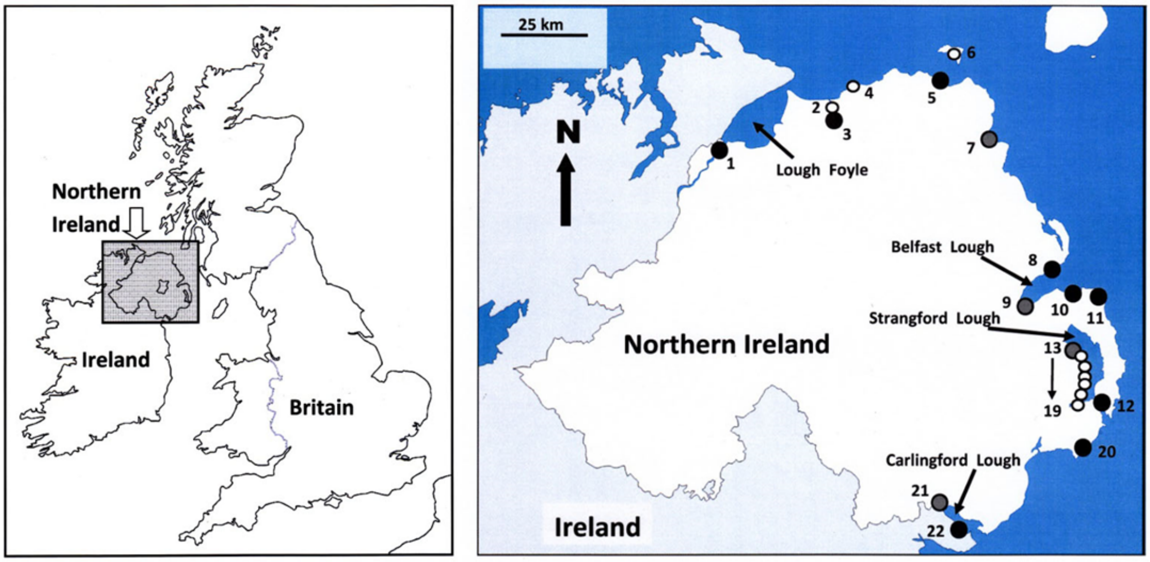

Figure 1. Map illustrating the island of Ireland, and indicating the Northern Ireland survey area with sample stations (for details of sites and presence of non-native species see Supplementary material Table S1).

gradually over time, acquire the same biological assemblages (Floerl and Inglis 2005). Given that leisure craft hulls are now considered to be a significant vector in the transmission of NIS (Minchin and Sides 2006), marinas are deemed suitable for the study of the general distribution of NIS in a region, and may be seminal points for regional colonisation. Within some bays and estuaries, the surface area of immersed anthropogenic structures suitable for settlement may greatly exceed the naturally available surfaces for colonisation. The high number of marinas worldwide (Cornell 2002) provides an increasing geographical coverage, making the availability of such sites for monitoring more extensive than before. Furthermore, marinas are often situated within ports or close to aquaculture sites. Recreational craft consequently play an important role in the dispersal of NIS both inter and internationally (Wasson et al. 2001). As a result, this may be one of the more important modes of spread ranging from ports to more remote regions.

According to Ramsar (2005), a rapid assessment is: "a synoptic assessment, which is often undertaken as a matter of urgency, in the shortest timeframe possible to produce reliable and applicable results for its defined purpose". In this study, we apply a rapid assessment to monitoring marinas using a target list of NIS.

The aim of this survey was to document records of NIS of marine Bryozoa from marinas along the coast of Northern Ireland. This information was used to define a baseline for the presence of NIS in the region, and to help inform future policy on the spread of NIS.

Methods

The floating structures supporting boardwalks, used as landing stages and for berthing at marinas, were monitored for the presence of selected NIS, including some cryptogens. Estuarine to marine sites, extending from Carlingford Lough to Lough Foyle in Northern Ireland (Figure 1), were examined. This included twelve marinas, eleven in Northern Ireland and one, Carlingford Marina, in the Republic of Ireland. In addition, eight pontoon landings were sampled for the presence or absence of NIS. Sampling took place from 28 August to 8 September 2012. Eight of the marinas visited in 2006 (Minchin 2007a) were revisited during this study. Selection of the additional sites was facilitated using *Google Earth*© images.

A target list of thirty-seven NIS and cryptogens was developed, in advance of the survey, known from elsewhere in the Republic of Ireland, Britain and northern Europe. Of these, four were bryozoan species. This included those species already present in the region, but likely to spread (Table 1).

Immersed surfaces of pontoons, supporting poles, fenders and fouled hulls were sampled using a 15 cm wide blade scraper with pocket net attached to an extendable pole. Net-sweeps, using a standard "kick-net", were used to remove fouling where soft organisms

Table 1. Species target list of bryozoans for pontoons, likely salinity zone and nearest region where known.

Species	< 30 psu	> 30 psu	Proximity	Substrate	Reference
Bugula neritina		x	Republic of Ireland	Hulls	Ryland et al. 2011
Schizoporella japonica		x	Holyhead, Wales	Fenders, Hulls	Ryland et al. 2014
Tricellaria inopinata	x	x	Northern Ireland	Hulls	Kelso and Wyse Jackson 2012
Watersipora subtorquata	x	x	Republic of Ireland	Hulls	Kelso and Wyse Jackson 2012

were dominant. Water temperature was measured using *Negrelli and Lambert* (LH1767) oceanographic reversing thermometer recorded to 0.5 °C; near-surface salinity was measured using an *Aquafauna* refractometer with an accuracy of ± 1 psu; and water transparency measured to the nearest 25 cm using a 30 cm diameter Secchi disc.

Some specimens were determined in the field; others were retained for later identification/confirmation by JSP and JSR.

Results and discussion

Salinities at sites ranged from 1 to 35 psu, with lowest levels in the more turbid waters of the Bann and Foyle Estuaries, and highest close to the open coast and within Strangford Lough. Temperatures were lowest at Rathlin Island, an area adjacent to strong tidal currents, and the furthest north. At most sites, water transparency exceeded 2.5 m, enabling direct observation (Supplementary material Table S1).

The Bangor and Ballycastle marinas, despite their relative proximity to marine conditions, were subject to freshwater runoff *via* storm drains. Bangor marina, in particular, had been subjected to considerable freshwater run-off during the summer period, changing the fouling community as observed during an earlier visit in 2012. The Foyle and Bann estuaries were persistently exposed to low salinities (Table S1), whereas fluctuating salinities from freshwater discharges occur at Belfast Port and Warrenpoint marinas and the Quoile pontoon in Strangford Lough.

During the survey, five NIS of Bryozoa were recorded (including the cryptogen *Bugulina fulva*):

two species were new to Northern Ireland;

Bugula neritina (Linnaeus, 1758)
Watersipora subatra (Ortmann, 1890)

new localities were found for three species;

Bugulina simplex (Hincks, 1886)
Bugulina fulva (Ryland, 1960)
Tricellaria inopinata d'Hondt and Occhipinti Ambrogi, 1985

Bugulina fulva (Figure 2)

This bryozoan was found on East Down Yacht Club, (Strangford Lough) and Rathlin Island pontoons in Northern Ireland, and from Carlingford Marina in the Republic of Ireland (det. JSP, conf. JSR).

Bugulina fulva was first recorded in Northern Ireland on 18 August 2012 by attendees at a Hydroid & Bryozoan Workshop from Strangford Lough (south of Walter's Rocks). It was subsequently recorded from Portaferry Marina and Limestone Reef during the same workshop. In the Republic of Ireland, it has been recorded from Barloge Creek and the Rapids in Lough Hyne, Co. Cork (23 July 2013).

The current status of *Bugulina fulva* is unknown, it is quite likely to be a NIS but is treated here as a cryptogen.

Bugula neritina (Figure 3)

Archived material collected by DM in January 2006 (Minchin 2007a) from Malahide Marina was subsequently identified as *Bugula neritina* by JSR. *Bugula neritina* was also collected (in abundance) from Carlingford Marina on 2 August 2008 by C. Maggs. It was present at both sites later in August and September 2008 (Ryland et al. 2011). Both the brown and purple forms were re-recorded from Carlingford Marina in 2012.

Bugula neritina (purple and brown forms) was found, abundant, attached to buoys and kelp stipes throughout Carrickfergus Marina, the first record for Northern Ireland. The bryozoan was found at all 30 sampling sites visited in the Marina, being abundant at one, and common at 5 others. A subsequent record of a bushy red/purple bryozoan from south of Abbey Rock, Strangford Lough (coll. H. Edwards, det. J. Nunn) on 21 August 2013 (Minchin and Nunn 2013) was recently redetermined as *Bugulina flabellata* (Thompson in Gray, 1848).

Bugulina simplex (Figure 4)

This bushy bryozoan was found at five sites during the present survey (Rathlin Island pontoon, and Ballycastle, Glenarm, Carrickfergus and Bangor Marinas). It had previously been collected only from

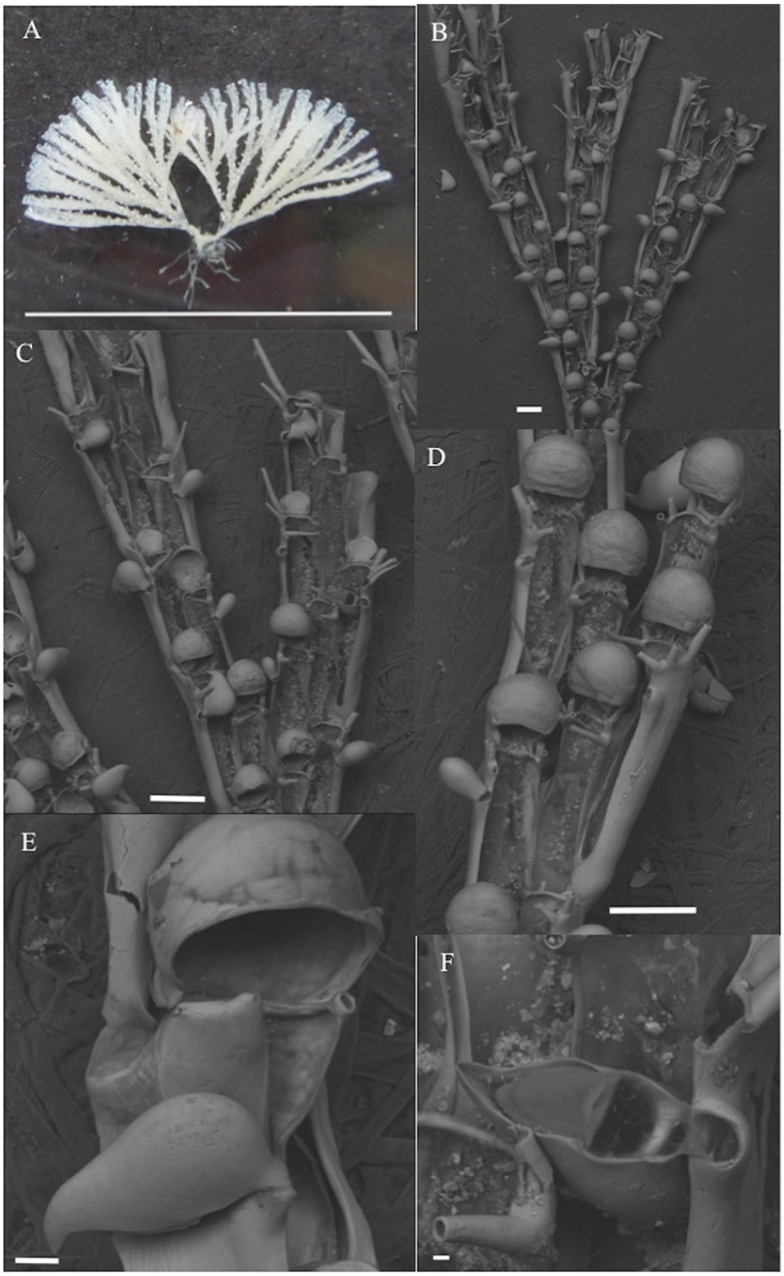

Figure 2. *Bugulina fulva* (MK388 Carlingford Marina). A) Light microscope image of a whole colony with rootlets (scale bar = 15 mm). B) Scanning Electron Microscope image of a colony branch (scale bar = 100 µm). C) Colony branch in closer detail showing ovicells, avicularia and spines (scale bar = 200 µm). D) Close up image of well-developed ovicells and clear view of the spine arrangements 3 on the outer corner and 2 on the inner corner (scale bar = 200 µm). E) Close up of a single zooid with ovicell and relatively large avicularium with hooked rostrum (scale bar = 30 µm). F) Close up view of the underside of the avicularium revealing the mandible still intact (scale bar = 10 µm).

Bangor Marina (2 August 2011 coll. JN, det. JSP), the first record for the island of Ireland. The species was recorded from Carrickfergus Marina again in September 2013.

It was first recorded in Britain more than fifty years ago from south Wales in the Milford Docks (Ryland 1958) and subsequently from North Wales in Holyhead Harbour, Belgium and Brittany. It is known from the Dutch coast where it is seasonally abundant, during August and September, at marinas (Ryland et al. 2011). More recently it has been recorded from the Shetland Islands (Collin et al. 2015). It was not found by Porter et al. (2015) during their survey along the coast of Norway between Bergen and Trondheim.

Watersipora subatra (Figure 5)

The first record for Northern Ireland of the red/orange form of *Watersipora subatra* was found in Ardglass.

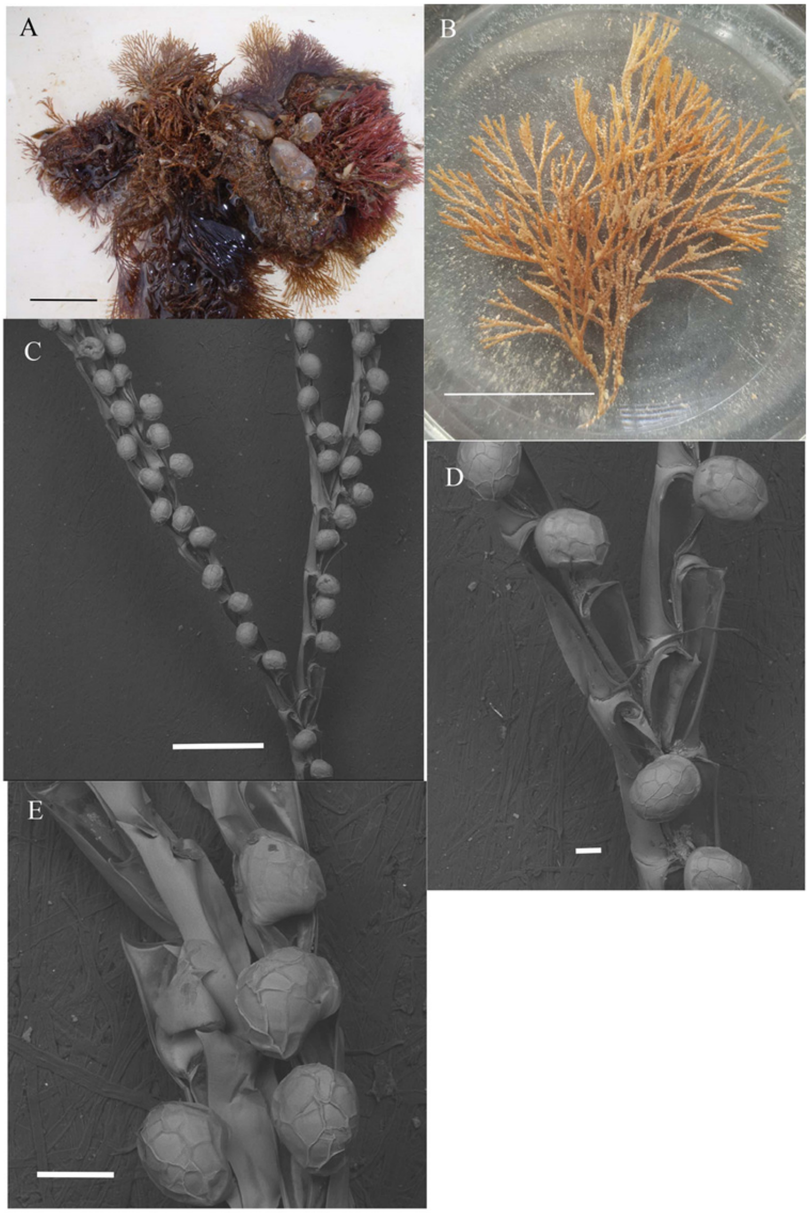

Figure 3. *Bugula neritina* (MK386 Carrickfergus Marina). A) Clump of purple coloured *Bugula neritina* colonies collected from Carrickfergus Marina (scale bar = 5 cm). B) Macro photograph of a whole colony in a petri dish (scale bar = 3 cm). C) Scanning Electron Microscope image of colony branch indicating arrangement of zooids and large numbers of globular ovicells (scale bar = 1 mm). D) Closer view of ovicell position on the zooid (scale bar = 100 µm). E) Close view of the ovicell situated on the zooid (scale bar = 200 µm).

Two colonies were found; one overgrowing the shell of a mussel and the other a sponge. A subsequent visit to the Marina and adjacent shore on 29 August 2014 failed to find any colonies.

This species was recently recorded from Dun Laoghaire Marina as *Watersipora subtorquata* (d'Orbigny, 1852) (Kelso and Wyse Jackson 2012) which is the first known record for the island of Ireland, a not unexpected occurrence. Colonies were found attached to floating dock pontoon in a shaded area. This record was subsequently reassigned to *Watersipora subatra* by Vieira et al. (2014). Colonies have been reported rafting in the North Sea on floating plastic and *Himanthalia*; they have not been recorded as settled on a fixed substrate in the region (Kuhlenkamp and Kind 2013). It has also been recorded from the Pacific (Gordon and Mawatari 1992) and Indonesia (Harmer 1957).

Tricellaria inopinata (Figure 6)

Tricellaria inopinata was first recorded from Northern Ireland from Bangor Marina on 22 August 2011 (Nunn et al. 2012), subsequently at Portrush

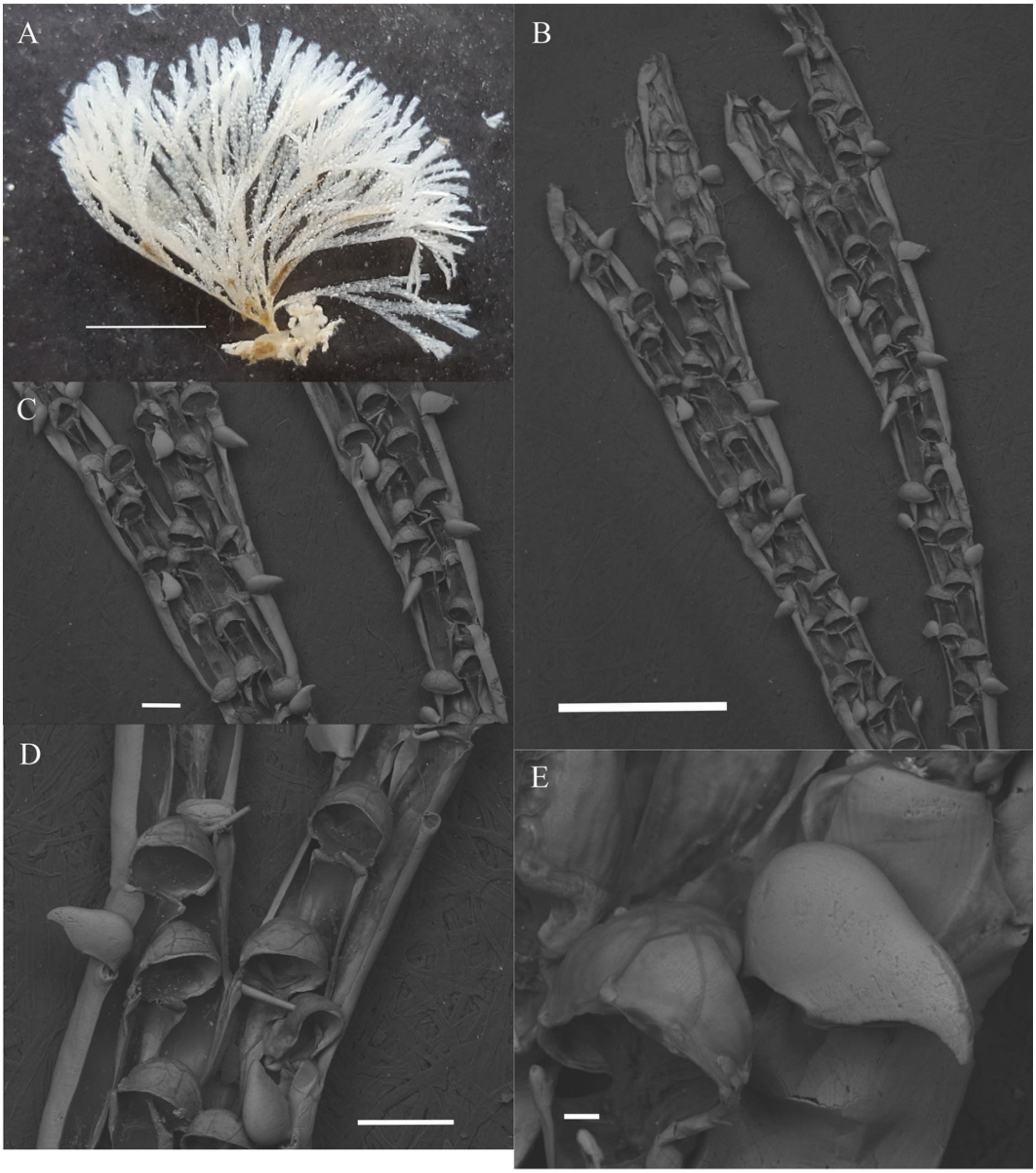

Figure 4. *Bugulina simplex* (MK390 Bangor Marina). A) Macro photograph of a whole colony (scale bar = 8 mm). B) Scanning Electron Microscope image of part of a colony branch illustrating arrangement of zooids, position of zooids, ovicells and avicularia (scale bar = 1 mm). C) Closer view of part of the colony branch clearly illustrating the position of the avicularium (scale bar = 200 µm). D) Closer view of a group of zooids illustrating the spine formula 1:1 and position of the avicularium (scale bar = 200 µm). E) Close up view of the avicularium (scale bar = 20 µm).

Harbour (12 October 2011), and again in Bangor Marina (14 June 2012). The species was confirmed from both those sites during the present survey, and in addition from Rathlin Island pontoon, and Glenarm, Ardglass, Carrickfergus and Carlingford marinas (det. JSP). The species was still present in Carrickfergus Marina in September 2013.

This species is known from the Republic of Ireland from Malahide and Carlingford in 2006 (Ryland et al. 2011), and has more recently been reported from

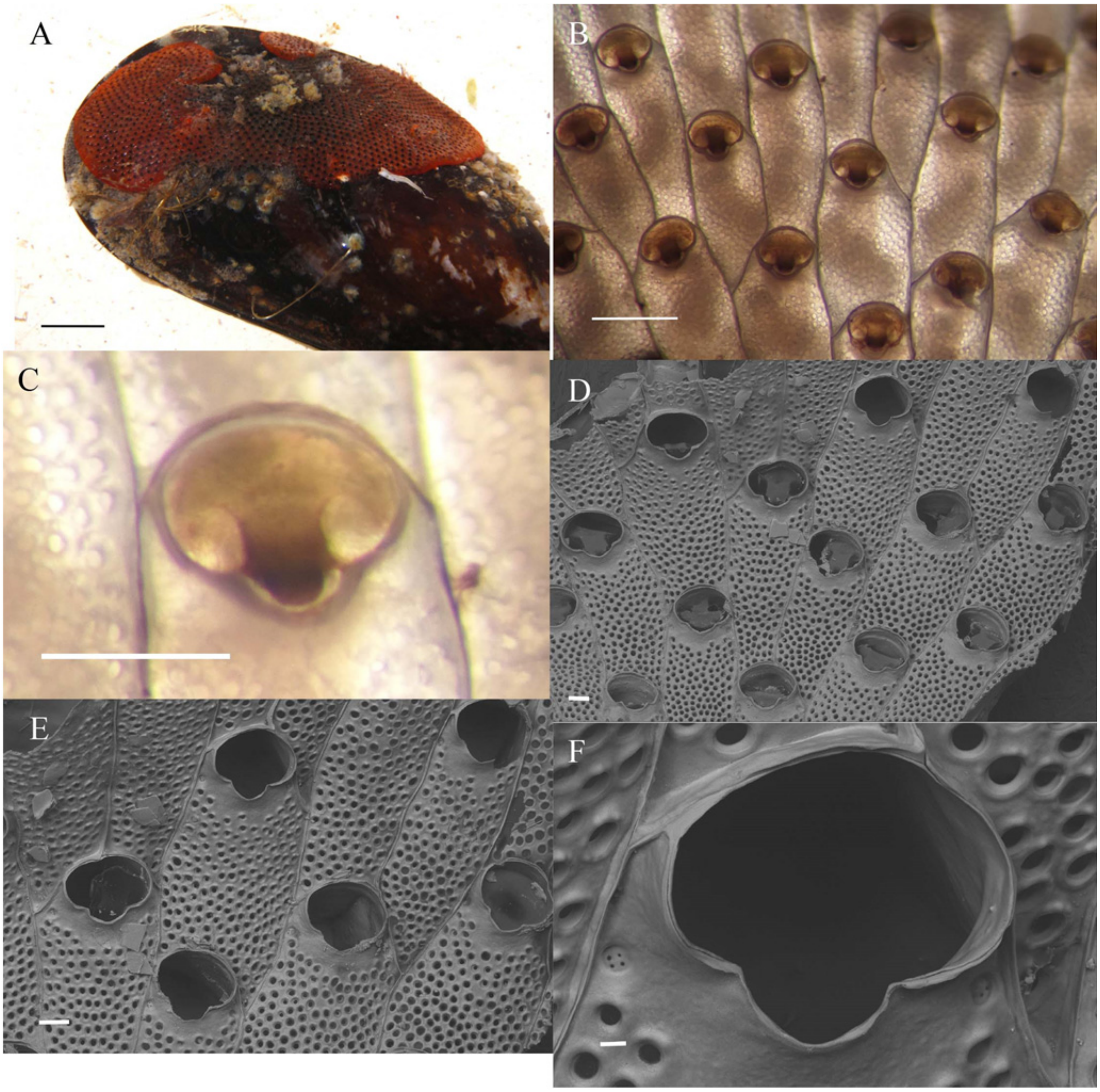

Figure 5. *Watersipora subatra* (MK389 Ardglass Marina). A) Macro photograph of a colony of *Watersipora subatra* encrusting a shell of the mussel *Mytilus edulis* at Ardglass Marina (scale bar = 2 cm). B) Light microscope image of part of the colony using transmitted light to illustrate zooid arrangement and shape of the orifice (scale bar = 300 µm). C) Light microscope image of a zooid orifice illustrating the shape of the sinus (scale bar = 200 µm). D) Scanning Electron Microscope image of a group of autozooids (scale bar = 100 µm). E) Closer view of a group of zooids focussing on the shape of the orifice (scale bar = 100 µm). F) Close view of the orifice and pore plates (scale bar = 20 µm).

Dublin Bay (Kelso and Wyse Jackson 2012). It has also been recorded from the intertidal in Mulroy Bay, Co. Donegal under the new Harry Blaney Bridge (22 June 2013, coll. JN, det. JSP).

Transport and monitoring of NIS in Irish waters

NIS continue to arrive in Irish waters, part of a continuing trend throughout many world regions (Rilov and Crooks 2009). For example, the NIS bryozoan *Schizoporella japonica* Ortmann, 1890 was not found during the 2012 survey conducted by Minchin and Nunn (2013). However, it has been found subsequently at Greystones marina in 2015 (Loxton et al. 2017). The increase in NIS records and their extent demonstrates that a greater frequency than six years for such studies is needed. The small numbers of *Watersipora subatra* indicate a possible early arrival, others may have been present for some years.

The majority of NIS occurring at marinas will probably have arrived on the hulls of leisure craft. Indeed *Bugula neritina* was found on the hulls of

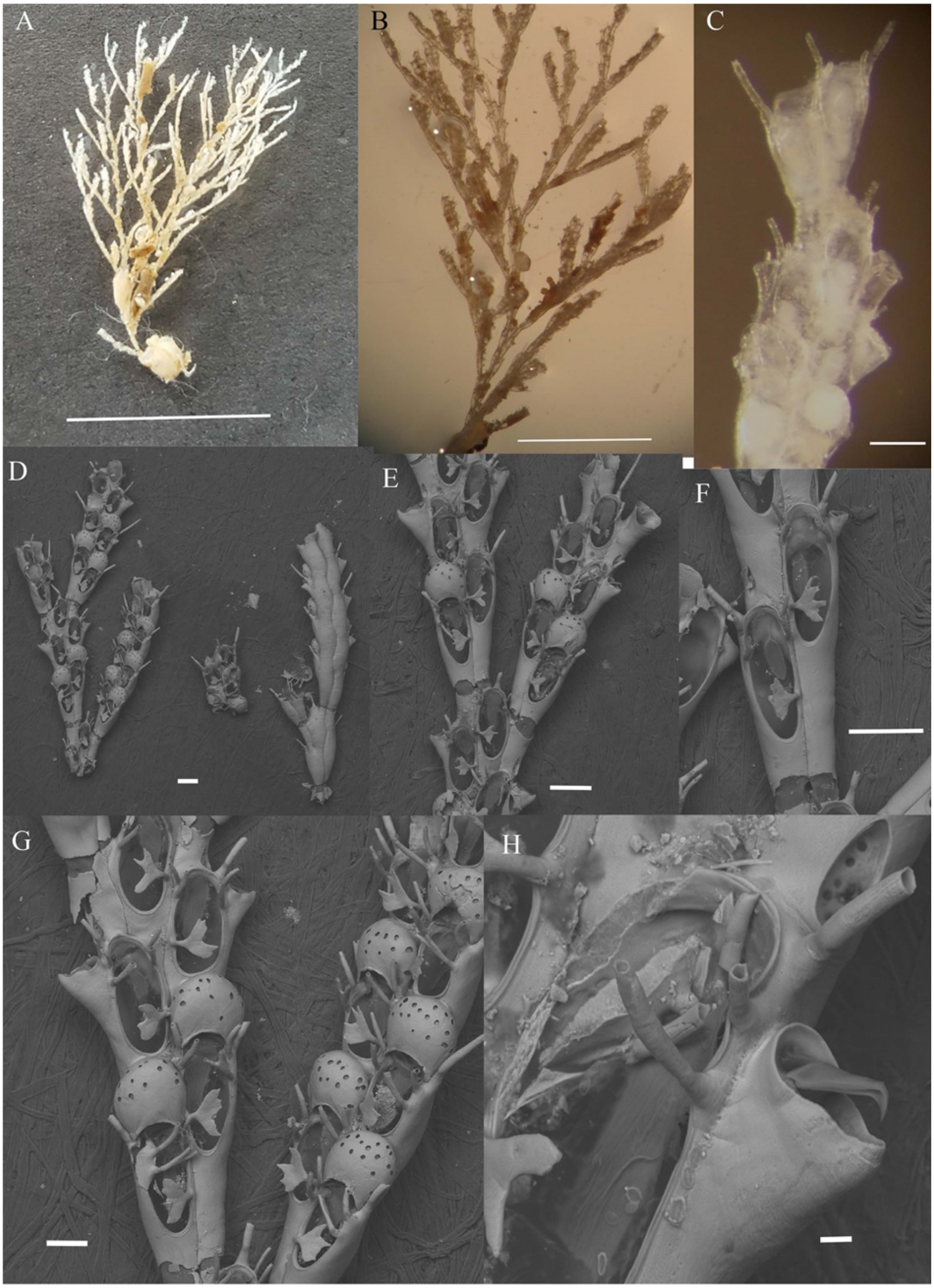

Figure 6. *Tricellaria inopinata* (MK387 Carrickfergus Marina). A) Macro photograph of a colony of *Tricellaria inopinata* showing the delicate branching growth form (scale bar = 1.5 cm). B) Light microscope image of colony with transmitted light showing the branch arrangement of the colony (scale bar = 1.5 cm). C) Closer view of the distal portion of a branch with transmitted light showing pattern of spines (scale bar = 200 µm). D) Low magnification (x50) Scanning Electron Microscope image of the front and back of colony branches (scale bar = 200 µm). E) Closer view of a branch portion with ovicellate zooids, spines and scutum clearly visible (scale bar = 200 µm). F) Portion of colony branch showing young zooids with intact spines and a branched scutum overarching the frontal membrane of the zooid (scale bar = 200 µm). G) Close up view of the ovicellate zooids, pores in the ovicells clearly visible and avicularia also in view (scale bar = 100 µm). H) Close up view of the lateral avicularium (scale bar = 20 µm).

leisure craft both in this study and earlier in 2006 (Minchin 2007a). Introductions may also occur as ballast discharges from commercial shipping within port regions via free-living stages. The majority of marine and brackish NIS have been recorded for the first time in the island of Ireland during the last decade. This includes specialist studies on bryozoans (Ryland et al. 2011; Nunn et al. 2012; Kelso and Wyse Jackson 2012). Bryozoa may have been spread *via* smaller craft to an expanding number of marinas, and pontoon landing stages, about the Irish coast. The natural spreading capabilities of these biota once established is little known.

The two main taxa that have arrived and expanded their range are bryozoans and tunicates. Different forms of some NIS have been recorded; the purple form of *B. neritina* was found at Carrickfergus, whereas the purple and brown forms were found at Carlingford. *W. subatra* has two colour forms which may be orange to brownish purple or greyish to black; only the orange form was represented by two colonies from Ardglass. *T. inopinata* is now widely established.

Ecological interactions of NIS Bryozoa

The ecological interactions of NIS Bryozoa are not yet clearly understood due to very few studies focussing on these aspects. There are two recent publications which provide preliminary data to a) quantify the viability of transported colonies and b) to start to understand the competitive interactions of NIS encrusting bryozoan colonies in relation to environmental conditions.

In Kuhlenkamp and Kind (2013), the NIS *Watersipora subatra* is reported to have arrived in Helgoland rafting on the floating macroalga *Himanthalia*. This study showed that natural algae were acting as a transport vector. One hundred and twenty basal holdfasts of *Himanthalia* were examined, and 8.3% of these were encrusted with viable colonies of *W. subatra*. Although rafting on macroalgae (and plastics) is a certain vector of transport of viable colonies of bryozoans, there is still no evidence of settlement of *Watersipora subatra* in the North Sea yet. The nearest known populations are in the English Channel (Channel Islands, Brittany).

Liu et al. (2017) investigated overgrowth competition between *Cryptosula pallasiana* and a species of *Watersipora* growing on the hull of a ship, which had been moored for nearly six years in Qingdao Harbour, in the Yellow Sea, China. While these species were not specifically described as being NIS, it was noted that the *Cryptosula* was more successful on the sunny side of the ship, whilst *Watersipora* did better on the shaded side. It would be interesting to see further ecological studies of this type to try to understand the specific impacts of NIS on native fouling bryozoans. In particular, studies on the impacts of light and shade would be of interest, given the types of surfaces available in pontoons and marinas.

NIS links with other regions

In this study, we have shown that rapid assessment surveys can produce fast results when combined with a target list of expected species. The numbers of new species and new localities found since 2006 would indicate that more frequent monitoring may be required to fully understand rates of infection and spread. A recent survey of NIS in Norway used a similar approach called the “Blacklist” as a tool for monitoring for the presence and introduction of NIS (Porter et al. 2015). A recommendation for the future should be to harmonise monitoring approaches so that invasives can be quickly identified as potential risks at regional scales.

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Supplementary material

The following supplementary material is available for this article:

Table S1. Records of non-native bryozoans in 2012 and environmental conditions at surveyed sites.

This material is available as part of online article from:
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