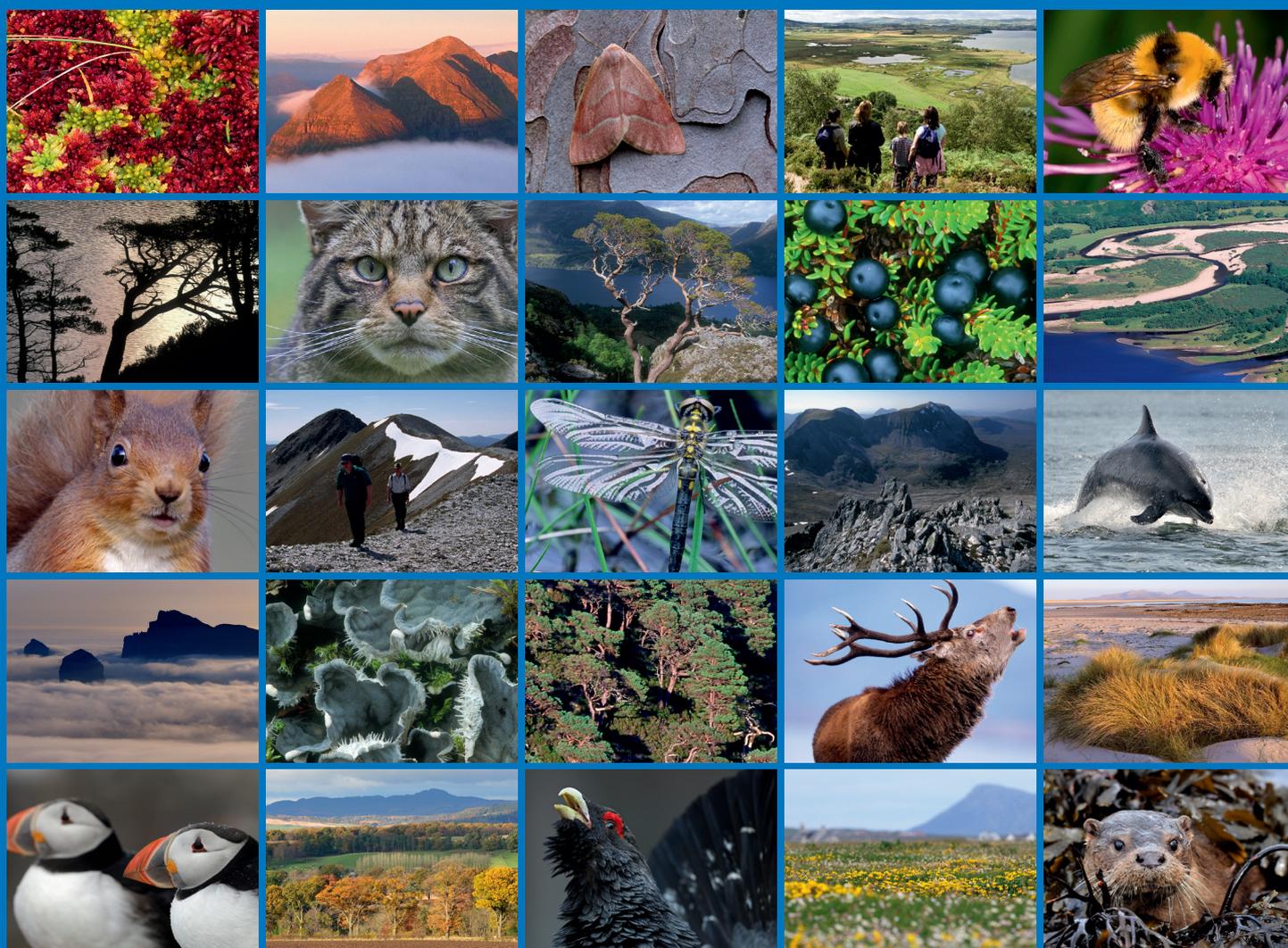


Initial response to the invasive carpet sea squirt, *Didemnum vexillum*, in Scotland





Scottish Natural Heritage
All of nature for all of Scotland

COMMISSIONED REPORT

Commissioned Report No. 413

Initial response to the invasive carpet sea squirt, *Didemnum vexillum*, in Scotland

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COMMISSIONED REPORT

Summary

Initial response to the invasive carpet sea squirt, *Didemnum vexillum*, in Scotland

Commissioned Report No. 413 (Project ID: 10701, 10751 and 10752)

Contractor: Scottish Association for Marine Science (SAMS); CB Marine Services

Year of publication: 2011

Background

The carpet sea squirt (*Didemnum vexillum*) is an invasive non-native species of colonial sea squirt that has recently been found in England, Ireland, Wales and at one location in the Clyde, on the west coast of Scotland. The potential ecological and economic impacts of this species are significant. A rapid response eradication programme in Holyhead Harbour is currently underway, showing signs of some success so far. However, it is not known how far this species has spread within the UK, and surveys are underway in England and Wales to determine its distribution. It is crucial to know as soon as possible how far it has spread, as this information will determine what the appropriate response will be - if it is confined to only a few sites, it may be possible to attempt eradication. If it is already more widespread, then containment or control measures will be more appropriate.

No specific surveys targeting this species had previously been carried out in Scotland, so it was not known whether it was present just in the one marina in the Clyde or whether it was more widespread. This project involved a series of rapid assessment surveys of those marinas and harbours thought to be most likely at risk from establishment (e.g. those in the Clyde and on the west coast of Scotland) and will inform SNH's policy for dealing with this species, as well as the wider UK policy for response.

Main findings

- *Didemnum vexillum* was only found in one out of the 12 marinas surveyed in south-west Scotland in February 2010: Largs Yacht Haven.
- Of the 12 additional sites surveyed in the vicinity of Largs Yacht Haven in April 2010, *D. vexillum* was observed at three locations: Fairlie Quay Jetty, Fairlie moorings and Clydeport Jetty.
- *D. vexillum* was well established throughout Largs Yacht Haven at a water depth between ~1 and 5 m and typically occurred on pilings, ropes, plastic cables, tyres, keep cages and on other marine organisms including the mussel *Mytilus edulis*, barnacles and the solitary tunicate *Ciona intestinalis*.
- *D. vexillum* was well established at Fairlie Quay Jetty at the low water level on ~70% of pilings. Fairlie moorings had one record and Clydeport had three records.
- *D. vexillum* was not found on suitable natural substrates on the seabed in the vicinity of Largs, suggesting a preference for artificial structures and/or vertical substrates.

- It is possible that *D. vexillum* was introduced to the marina, nearby jetties and moorings via hull fouling on vessel(s) during 2009.
- As an initial step in management of this species, a total of 147 hanging items were removed from the pontoons in Largs Yacht Haven. These ranged from short pieces of lightly fouled rope to tyres and heavily fouled ropes and settlement panels and included three anchor chains. Of the items removed, 65 were found to be colonised by *D. vexillum*.
- If allowed to disperse from this site, *D. vexillum* poses a considerable risk to the Scottish aquaculture industry and to marine habitats of conservation value.
- Increased awareness of *D. vexillum* and clear guidelines on how to minimise the spread of this species must be urgently produced in close collaboration with the commercial and recreational maritime sector.

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Table of Contents		Page
1	INTRODUCTION	1
2	METHODS	3
	2.1 Marina surveys	3
	2.2 Detailed inspection of Largs Yacht Haven	4
	2.3 Surveys of artificial structures around Largs	4
	2.4 Surveys of the seabed around Largs	7
	2.5 Clean-up of fouled items in Largs Yacht Haven	8
3	RESULTS	9
	3.1 Marina surveys	9
	3.2 Detailed inspection of Largs Yacht Haven	9
	3.3 Surveys of artificial structures around Largs	13
	3.4 Surveys of the seabed around Largs	17
	3.5 Clean-up of fouled items in Largs Yacht Haven	18
	3.6 Additional non-native species	19
4	DISCUSSION	21
	4.1 Dispersal vectors	21
	4.2 Implications for future spread	22
	4.3 The importance of regular monitoring	22
5	CONCLUSIONS	23
6	REFERENCES	24

List of Figures **Page**

Figure 1.1 Confirmed sightings (including year of first record) of *D. vexillum* in the UK and Ireland, up to 2010. 2

Figure 2.1 The location of the 12 survey sites in south-west Scotland. 3

Figure 2.2 The location of the 12 survey sites in the Firth of Clyde 6

Figure 2.3 The approximate locations of the eleven ROV survey sites 7

Figure 3.1 The location of colonies of *D. vexillum* on submerged items, including ropes, keep cages, plastic cables, settlement panels, pontoon floats and tyres in Largs Yacht Haven, in addition to the pilings. 12

Figure 3.2 Locations of artificial structures surveyed around Largs..... 13

List of Tables **Page**

Table 2.1 Location, survey date, weather conditions and water visibility at the 12 survey sites inspected on the west coast of Scotland for *D. vexillum*. 4

Table 2.2 Location, survey date and method of access, at the 12 survey sites inspected in the vicinity of Largs Yacht Haven for *D. vexillum* 5

Table 3.1 Description of ROV survey sites 17

Table 3.2 Number of items removed from the pontoons and the percentage of colonised material. 18

Table 3.3 Location of additional non-native species found during the *Didemnum vexillum* survey. 19

List of Photographs **Page**

Photo 3.1 *D. vexillum* on piling in Largs Yacht Haven (seen as a pale coloured growth form overgrowing barnacles just below the macroalgae) (C. Beveridge, SAMS)..... 9

Photo 3.2 *D. vexillum* on submerged rope in Largs Yacht Haven (seen as a pale coloured growth form, clearly showing the characteristic water channels as darker leaf-like veins radiating out from pores within the colony) (C. Beveridge, SAMS). 10

Photo 3.3 *D. vexillum* on submerged tyres in Largs Yacht Haven (seen as a pale coloured growth form on all three tyres) (C. Beveridge, SAMS). 11

Photo 3.4 *D. vexillum* on creel (or 'keep cage') in Largs Yacht Haven (seen as a pale coloured growth form coating the mesh enclosure) (C. Beveridge, SAMS)..... 11

Photo 3.5 *D. vexillum* on a rope attached to Fairlie Quay Jetty (C. Beveridge, SAMS)..... 14

Photo 3.6 *D. vexillum* on piling of Fairlie Quay Jetty (C. Beveridge, SAMS). 14

Photo 3.7 *D. vexillum* seen as creamy areas at the water line on the left hand pilings of Fairlie Quay Jetty (C. Beveridge, SAMS)..... 15

Photo 3.8 Clydeport Jetty viewed from the south (C. Beveridge, SAMS). 15

Photo 3.9 *D. vexillum* on piling of Clydeport Jetty (C. Beveridge, SAMS). 16

Photo 3.10 Underwater photograph of *D. vexillum* on piling of Clydeport Jetty (C. Beveridge, SAMS)..... 16

Photo 3.11 Underwater photograph of *D. vexillum* seen as a creamy patch on the left side of a ladder of Clydeport Jetty (C. Beveridge, SAMS)..... 17

Photo 3.12 Underwater photograph of *D. vexillum* on the mooring chain of a navigation buoy at Site 3 (SNH)..... 18

Photo 3.13 *Corella eumyota* at the base of a piling under Wemyss Bay Cal Mac pier. (C. Beveridge, SAMS). 20

Photo 3.14 *Corella eumyota* at the base of a piling under Wemyss Bay Cal Mac pier with in the centre a small patch of *Botrylloides violaceus* (ID confirmation required). (C. Beveridge, SAMS)..... 20

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1 INTRODUCTION

Didemnum vexillum (Kott, 2002) is an invasive non-native species of colonial sea squirt that has become established worldwide (see Lambert, 2009 for review). This species has recently been found on the south coast of England (J. Bishop, MBA, pers. comm.), Ireland (Minchin & Sides, 2006; Minchin, D., pers. comm.) and Wales (Holt *et al.*, 2009) (Figure 1.1). *D. vexillum* can exhibit a variety of growth forms, including mat- or sheet-like colonies with short lobe-like structures and rope or beard-like colonies which typically hang from hard substrates such as ship hulls, docks and ropes. It reproduces rapidly, both sexually and asexually (Lambert, 2009) and it is highly likely that it is spread through hull fouling, the transfer of aquaculture equipment and stock, and ship ballast water rather than natural dispersal, as the larvae only survive for a few hours in the water column (Minchin & Sides, 2006).

D. vexillum was confirmed in November 2009 for the first time in Scotland in Largs Yacht Haven located in the Firth of Clyde during a routine non-native species survey of marinas by researchers from the Scottish Association for Marine Science (SAMS). This survey had also been conducted by SAMS at two other marinas; Clyde Ardrossan and Troon and no sign of *D. vexillum* had been found. Previous surveys for non-native species in the 10 largest marinas in Scotland in August 2006 (Ashton *et al.*, 2006), 2007 and 2008 (Cook, unpublished data) did not find any sign of *D. vexillum*, suggesting that this introduction in Largs Yacht Haven occurred in 2009. No surveys specifically targeting this species have been carried out in Scotland, with the exception of the three marinas in the Clyde in 2009, so it was unknown whether this species has been introduced elsewhere.

The potential ecological and economic impacts of this species are significant, including the overgrowth of fish spawning grounds (Valentine *et al.*, 2007), the prevention of demersal fish species foraging on benthic prey and the interference with aquaculture (fin- and shellfish), fishing and other coastal and offshore activities (USGS, 2010). A rapid response eradication programme in Holyhead Harbour is currently underway, showing signs of some success so far. However, it is not known how far this species has already spread within the UK, and further surveys are underway in England and Wales to determine its distribution. It is crucial to know as soon as possible how far it has spread, as this information will determine what the appropriate response will be - if it is confined to only a few sites, it may still be possible to attempt eradication. If it is already more widespread, then containment or control measures will be more appropriate.

The aim of this project was to determine the presence or absence of the invasive marine non-native *D. vexillum* on the south-west coast of Scotland. The first survey involved a series of rapid assessment surveys of those marinas and harbours thought to be most likely at risk from establishment (e.g. those in the Clyde). This was followed up by additional surveys of artificial and natural substrates in the vicinity of Largs Yacht Haven. The results of these surveys will inform SNH's policy for dealing with this species, as well as the wider UK policy for response.

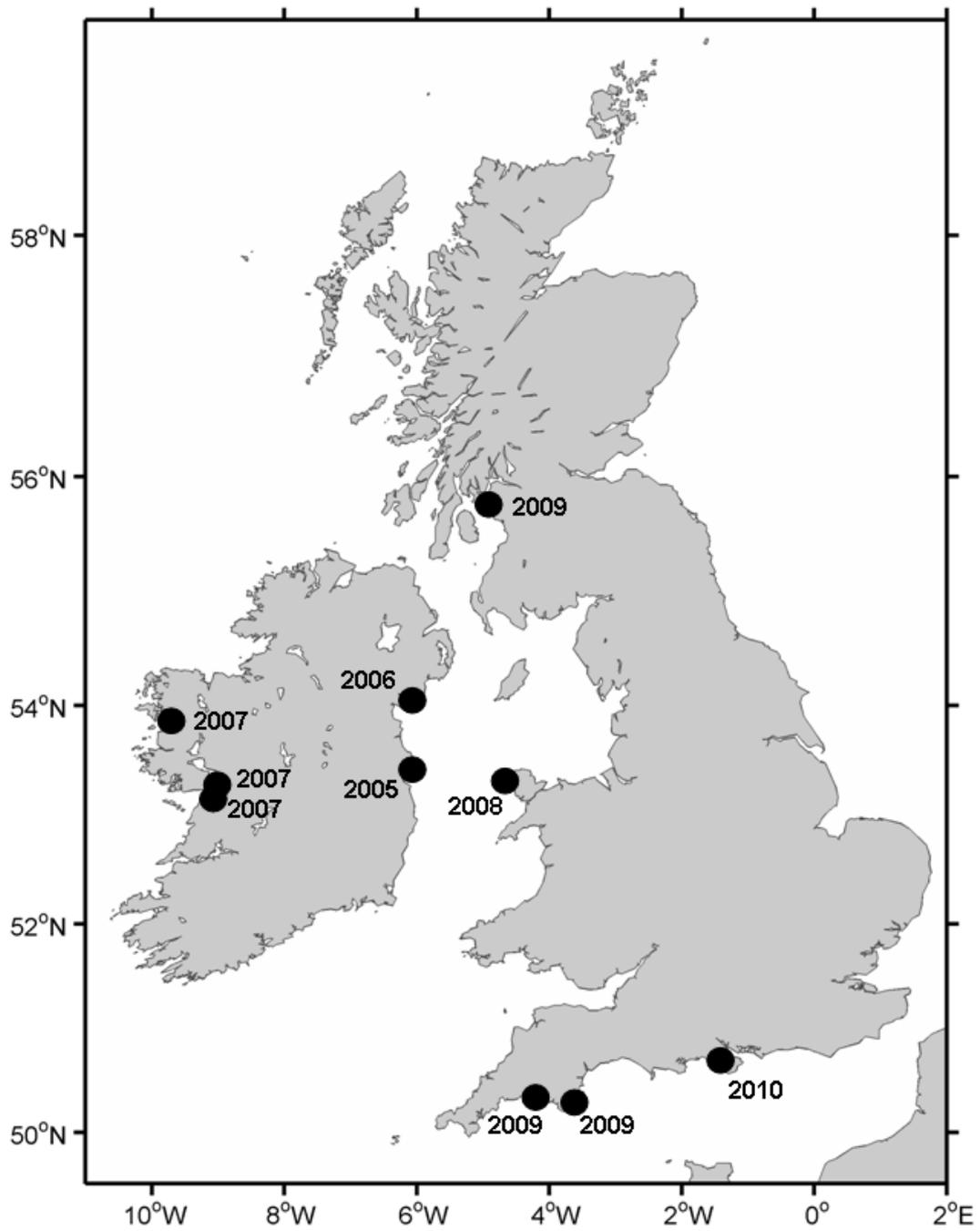


Figure 1.1 Confirmed sightings (including year of first record) of *D. vexillum* in the UK and Ireland, up to 2010.

2 METHODS

2.1 Marina surveys

Twelve locations, including ten marinas and two harbours on the west coast of Scotland (Figure 2.1; Table 2.1) were surveyed for *D. vexillum* between 1 and 5 February 2010 following a similar method described in Ashton *et al.* (2006) and the method adopted by the Marine Biological Association UK in on-going surveys for this species in England (J. Bishop, pers. comm.).

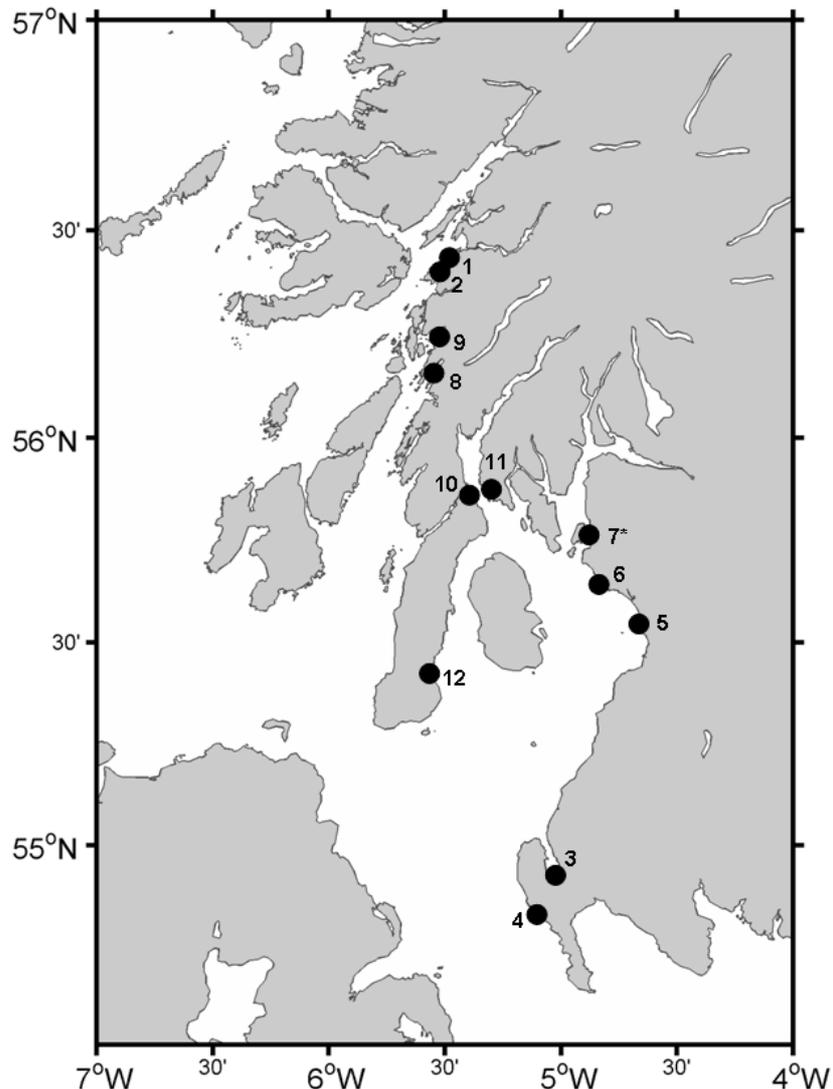


Figure 2.1 The location of the 12 survey sites in south-west Scotland; 1. Dunstaffnage, 2. Oban, 3. Stranraer, 4. Portpatrick, 5. Troon, 6. Clyde Ardrrossan, 7*. Largs Yacht Haven (*D. vexillum* identified at this site in November 2009), 8. Ardfern, 9. Craobh Haven, 10. Tarbert, 11. Portavadie, 12. Campbeltown.

A methodical search of pontoon floats, anchor chains, pilings and any ropes or other items hanging into the water at each location was carried out for signs of *D. vexillum* by three researchers from the Scottish Association for Marine Science (SAMS). All the pontoons in

the marina were inspected using viewing scopes and an underwater camera system operated from the pontoon walkway to collect video (Panasonic Optio W30 camera mounted on 2 m pole) and stills (Panasonic Optio W60 camera). Scrapers with fine mesh nets attached were also used to collect any suspect organisms for closer inspection. Surveys typically lasted between one and two hours depending on the size of the marina or harbour. The most effective survey method was for the group of researchers to stay together, with one person allocated to each of the side pontoons and the third person looking at the main walkway. This allowed instant confirmation by the survey team of any potential sightings of *D. vexillum*. Any additional non-native species found during the survey were recorded. Weather conditions and visibility of the water column was noted at each location. All the equipment was cleaned with sanitiser and the nets on each scraper changed between locations. Samples requiring verification were collected and preserved in alcohol for later inspection under a stereomicroscope.

Table 2.1 Location, survey date, weather conditions and water visibility at the 12 survey sites inspected on the west coast of Scotland for D. vexillum.

	Location	OS Grid Reference	Date	Wind	Precipitation	Water visibility
1	Dunstaffnage	NM 885 340	01/02/2010	calm	dry	very good
2	Oban	NM 843 305	01/02/2010	calm	dry/shower	very good
3	Stranraer	NX 058 611	02/02/2010	calm	drizzle	turbid
4	Portpatrick	NW 998 540	02/02/2010	slight breeze	dry/overcast	turbid
5	Troon	NS 311 312	02/02/2010	calm	dry/sunny	good
6	Clyde	NS 226 420	03/02/2010	calm	dry	good
7	Largs	NS 207 569	03/02/2010	calm	dry	good, but reduced at edges
8	Ardfern	NM 810 044	04/02/2010	breezy	dry	good
9	Craobh Haven	NM 794 077	04/02/2010	slight breeze	dry	good
10	Tarbert	NR 886 688	05/02/2010	calm	dry	turbid
11	Portavadie	NR 928 694	05/02/2010	calm	drizzle	good
12	Campbeltown	NR 721 204	05/02/2010	calm	dry/sunny	slightly turbid

2.2 Detailed inspection of Largs Yacht Haven

As *D. vexillum* had previously been found at Largs Yacht Haven in November 2009, a more detailed, three-hour survey was conducted to determine the full extent of colonisation by this species.

2.3 Surveys of artificial structures around Largs

Twelve locations, including two marinas, eight piers and two areas of swinging moorings in the vicinity of Largs Yacht Haven on the west coast of Scotland (Table 2.2; Figure 2.2) were surveyed for *D. vexillum* on 12 and 13 April 2010 following a similar method described in Section 2.1. Access to some of the sites was by rigid-hulled inflatable boat (RHIB) hired from Cumbrae Watersports Centre. Sites were visited at or near the time of low tide. Weather conditions on both days of the survey were good: dry and calm, with good visibility in the water.

Table 2.2 Location, survey date and method of access, at the 12 survey sites inspected in the vicinity of Largs Yacht Haven for D. vexillum

	Location	OS Grid reference.	Date	Access
1	Holyloch Marina, by Dunoon	NS165805	12/04/2010	On foot
2	Kip Marina	NS203722	13/04/2010	On foot
3	Wemyss Bay Cal Mac Pier	NS193685	13/04/2010	On foot at low water
4	Largs Cal Mac Pier	NS200595	13/04/2010	From RHIB
5	Largs moorings	NS205576	13/04/2010	From RHIB
6	Fairlie Quay Jetty (Admiralty Pier)	NS205563	12/04/2010	From RHIB
7	Fairlie Quay moorings	NS202553	12 and 13/04/2010	From RHIB
8	Clydeport jetty	NS193547	12/04/2010	From RHIB
9	Hunterston power station pier	NS175507	12/04/2010	From RHIB
10	Millport Pier	NS161546	12/04/2010	From RHIB
11	UMBSM Keppel Pier	NS178544	12/04/2010	From RHIB
12	Cumbræ Water Sports pier and pontoon	NS183580	13/04/2010	From RHIB

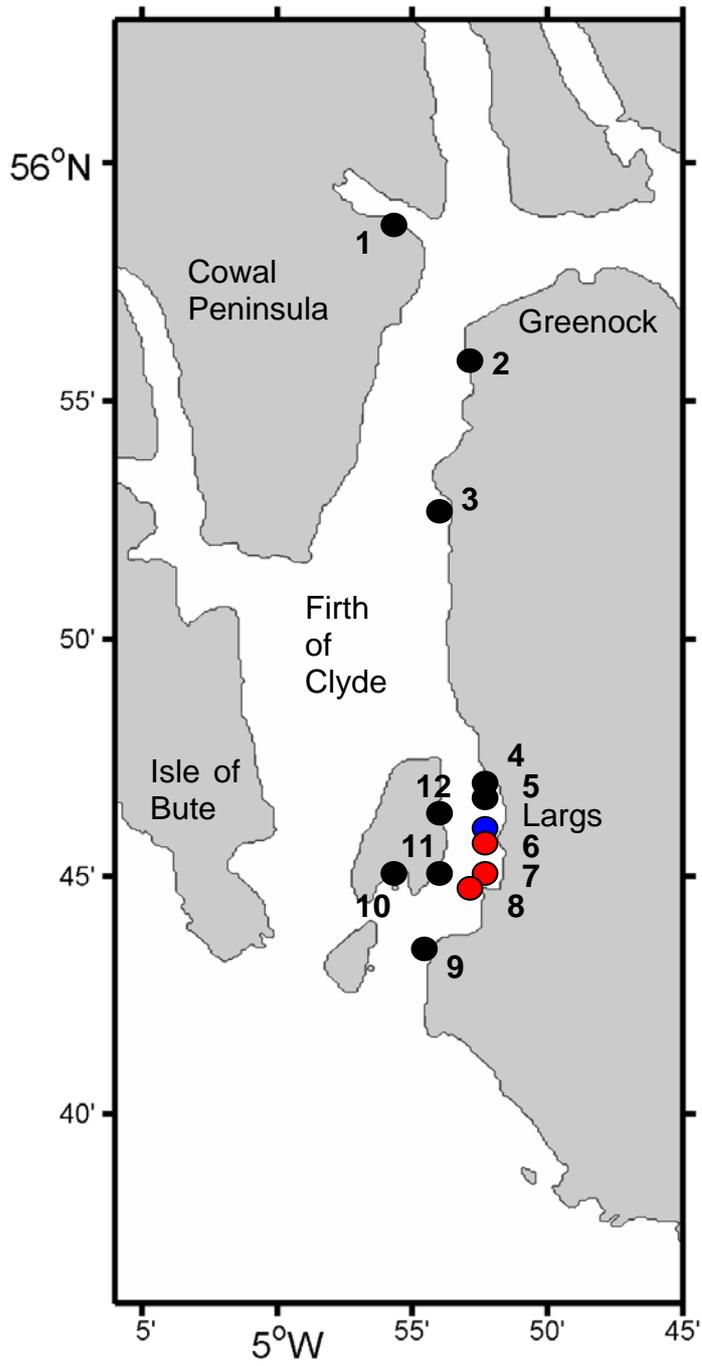


Figure 2.2 The location of the 12 survey sites in the Firth of Clyde with *D. vexillum* observed (red dots), not observed (black dots); 1 Holyloch Marina, by Dunoon, 2. Kip Marina, 3. Wemyss Bay Cal Mac Pier, 4. Largs Cal Mac Pier, 5. Largs moorings, 6. Fairlie Quay Jetty (Admiralty Pier), 7. Fairlie Quay moorings, 8. Clydeport jetty, 9. Hunterston power station pier, 10. Millport Pier, 11. UMBSM Keppel Pier, 12. Cumbrae Water Sports pier and pontoon

2.4 Surveys of suitable natural substrates on the seabed around Largs

Natural substrates on which *D. vexillum* could potentially grow were surveyed using a remotely operated vehicle (ROV) on 29 and 30 July operated from the *RV Actinia*. Video footage and still photographs were obtained from the seabed in the vicinity of Largs Yacht Haven and the Clydeport jetty from a camera mounted in a Video Ray ROV. Sites were selected based on areas marked on the chart as hard ground, and through discussion with scientists at the University Marine Biological Station Millport and the skipper and crew of the *RV Actinia*, all of whom have a good knowledge of the area.

ROV dives were made at eleven sites (Figure 2.3), each lasting a variable amount of time depending on the nature of the seabed and the direction of the current. One of the survey team monitored the onboard screen at all times. Where a suspected *D. vexillum* sighting was made sufficient time was taken to confirm whether or not the species in question was *D. vexillum*. The majority of the ROV dives were focused on suitable natural seabed habitats, except for the dive at Site 3 which looked at a mooring chain of a navigation buoy. Substrate type and characteristic species on the seabed were recorded, as well as depth, time, temperature and presence/absence of *D. vexillum*.

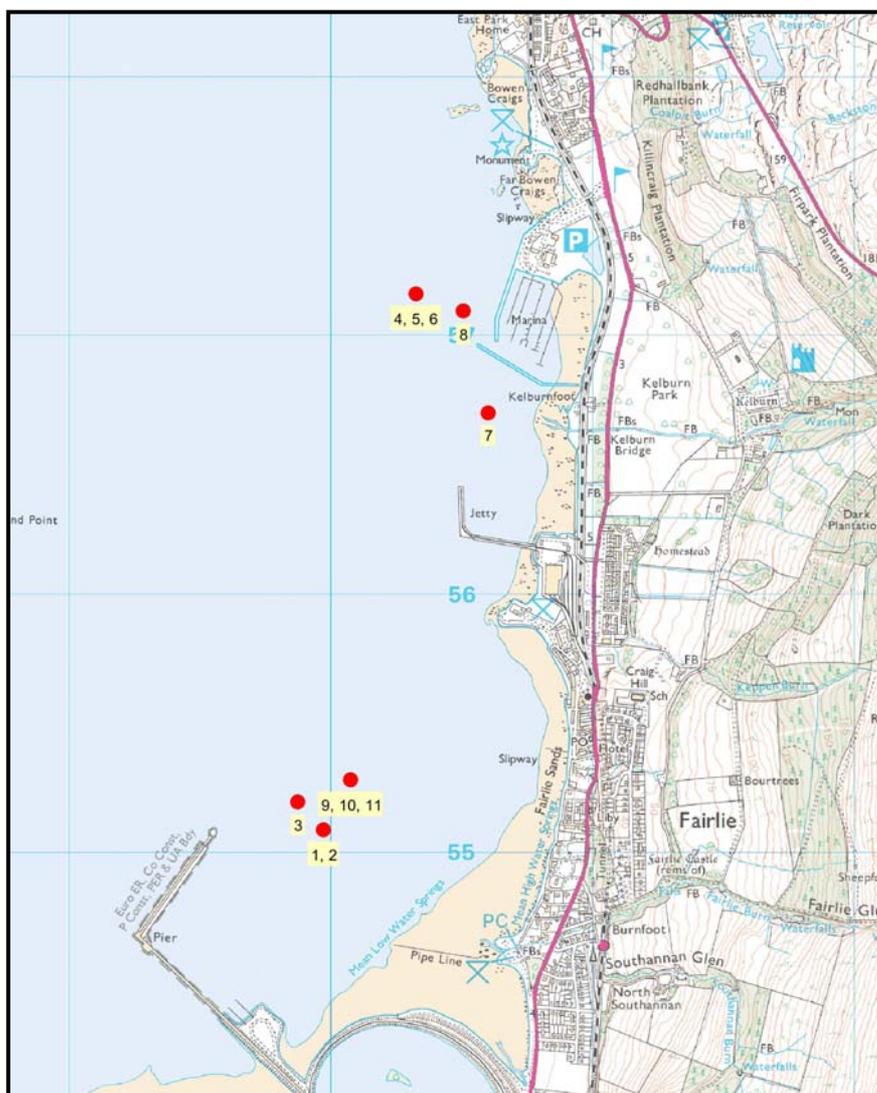


Figure 2.3 The approximate locations of the eleven ROV survey sites

2.5 Clean-up of fouled items in Largs Yacht Haven

As an initial step towards managing this invasive species, and to reduce the number of potential colonisation sites, CB Marine Services was contracted to remove any loose or hanging material colonised by *D. vexillum*. The SAMS survey identified colonies of *D. vexillum* on a range of items attached to the marina pontoons: ropes, tyres, cables and keep cages.

Largs Yacht Haven has seven pontoon legs each with a double letter designation indicating berths with finger pontoons on either side of the central pontoon. An estimate using a satellite image suggested well over 2000 m of main pontoons, without considering the fingers. Approximately 700 vessels are moored here over the summer.

Items hanging from the pontoons were assessed as to their likely value to adjacent boat owners. Items considered to be of value were removed from the water and secured to the pontoon. Power cables and hoses hanging from the pontoon were, where possible, secured clear of the water. Items not considered to be of value were removed by hand and lifted into a polythene-lined trolley or polythene bags and taken to the skips (destined for landfill) already present at the marina. Items were considered not to be of value where they had been in the water sufficiently long to carry significant fouling. Ineffective tyres and other fendering were also removed. Identification of *D. vexillum* was confirmed during a preliminary meeting with SAMS staff at Largs Yacht Haven.

3 RESULTS

3.1 Marina surveys

Of all the marinas surveyed, *Didemnum vexillum* was only found in Largs Yacht Haven where it had been previously identified in a routine survey of the marina in November 2009. *D. vexillum* was found almost immediately attached to a plastic cable hanging in the water, near the base of the entry ramp closest to the marina reception. A colony of this species was also found attached to the side of a nearby piling.

3.2 Detailed inspection of Largs Yacht Haven

A detailed inspection, using viewing scopes, of the pilings accessed by the ramp leading to pontoons A –F (Figure 3.1) found colonies of *D. vexillum* on ~60% of the pilings along the pontoon identified as A/B; ~80% of the pilings along pontoon C/D and on ~70% of the pilings along pontoon E/F (Photo 3.1).



Photo 3.1 *D. vexillum* on piling in Largs Yacht Haven (seen as a pale coloured growth form overgrowing barnacles just below the macroalgae) (C. Beveridge, SAMS).

The survey team, however, was unable to confirm the presence or absence of *D. vexillum* in the second section of the marina (pontoons G to P), which is accessed by a separate ramp, as the flooding spring tide had raised the pontoons to a height that made the viewing of any colonies of *D. vexillum* impossible with the survey equipment available. However, colonies of *D. vexillum* were observed on almost all of the submerged ropes found throughout the marina (13 out of 15 ropes inspected), particularly at a depth range of 1 m to 5 m (Photo 3.2).



Photo 3.2 D. vexillum on submerged rope in Largs Yacht Haven (seen as a pale coloured growth form, clearly showing the characteristic water channels as darker leaf-like veins radiating out from pores within the colony) (C. Beveridge, SAMS).

In addition, *D. vexillum* was well established on settlement panels (origin unknown) located at the end of the N/P pontoon at a depth of ~2 m. This suggests that there is a high likelihood that *D. vexillum* would also be found on the pilings in the second section of the marina. Colonies of *D. vexillum* were also observed on plastic cables, pontoon floats, tyres and creels (or 'keep' cages) found suspended from the marina pontoons (Photos 3.3 & 3.4) and their exact location can be seen in Figure 3.1.



Photo 3.3 D. vexillum on submerged tyres in Largs Yacht Haven (seen as a pale coloured growth form on all three tyres) (C. Beveridge, SAMS).



Photo 3.4 D. vexillum on creel (or 'keep cage') in Largs Yacht Haven (seen as a pale coloured growth form coating the mesh enclosure) (C. Beveridge, SAMS).

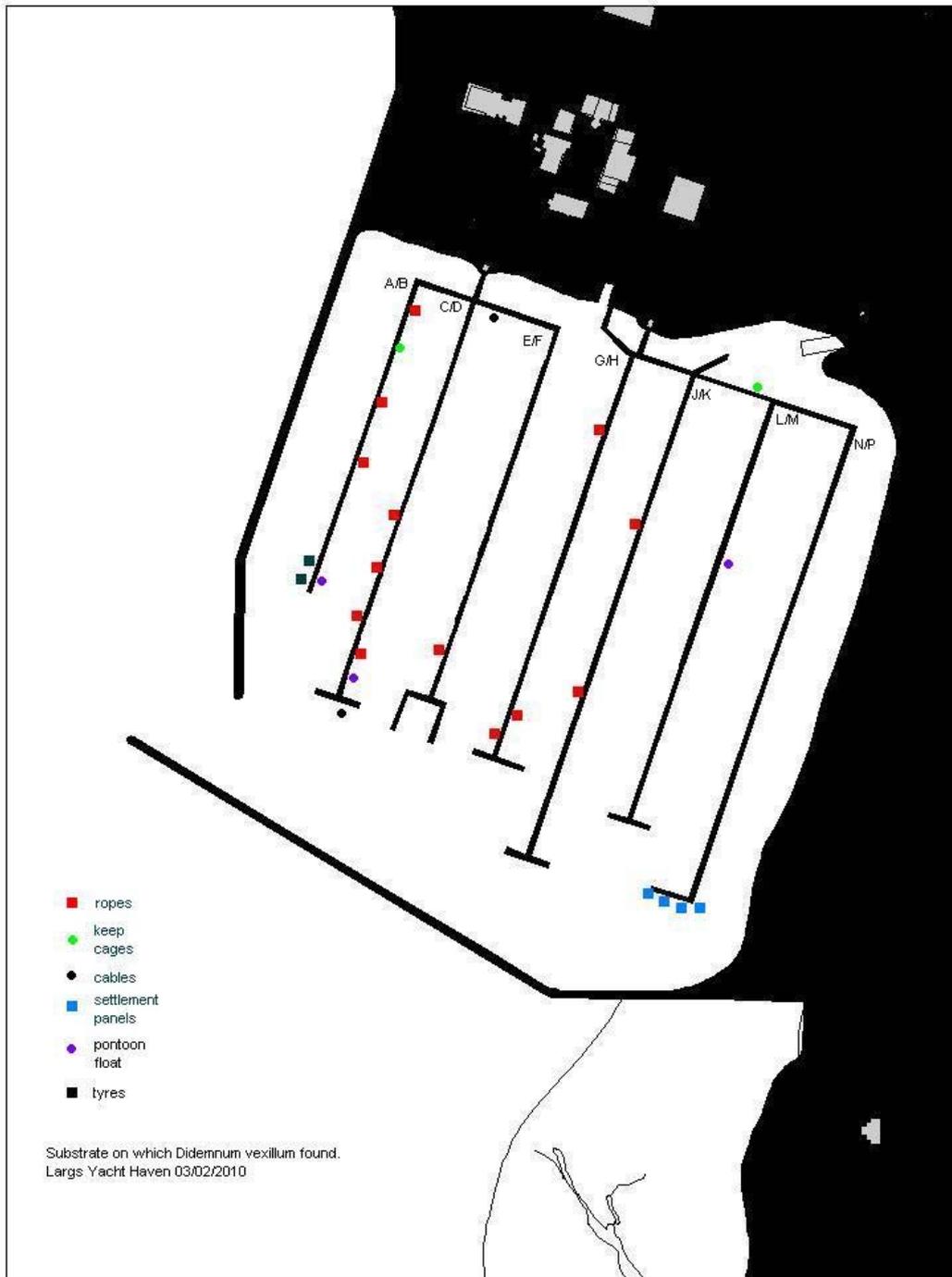


Figure 3.1 The location of colonies of *D. vexillum* on submerged items, including ropes, keep cages, plastic cables, settlement panels, pontoon floats and tyres in Largs Yacht Haven, in addition to the pilings.

3.3 Surveys of artificial structures around Largs

D. vexillum was observed at three locations of the 12 surveyed (indicated by red in Figure 2.2, Figure 3.2). Fairlie Quay Jetty (previously known as the Admiralty Pier) lies just south of Largs Yacht Haven and boats regularly move between the two and onto the Fairlie moorings. One rope hanging from the jetty had *D. vexillum* present (Photo 3.5) and this was removed. On returning to the site at low water the following day, *D. vexillum* was observed on ~70% of the pilings around the low water level (Photos 3.6 and 3.7).

Fairlie moorings are well maintained and mostly laid in the spring; however, *D. vexillum* was found here on the rope of a small marker buoy.

Clydeport Jetty (Photo 3.8) is a long L-shaped jetty used by large vessels to import coal. *D. vexillum* was observed here in three locations: at the low water level on two pilings (Photo 3.9 and 3.10) and a ladder on the outer part of the jetty (Photo 3.11).

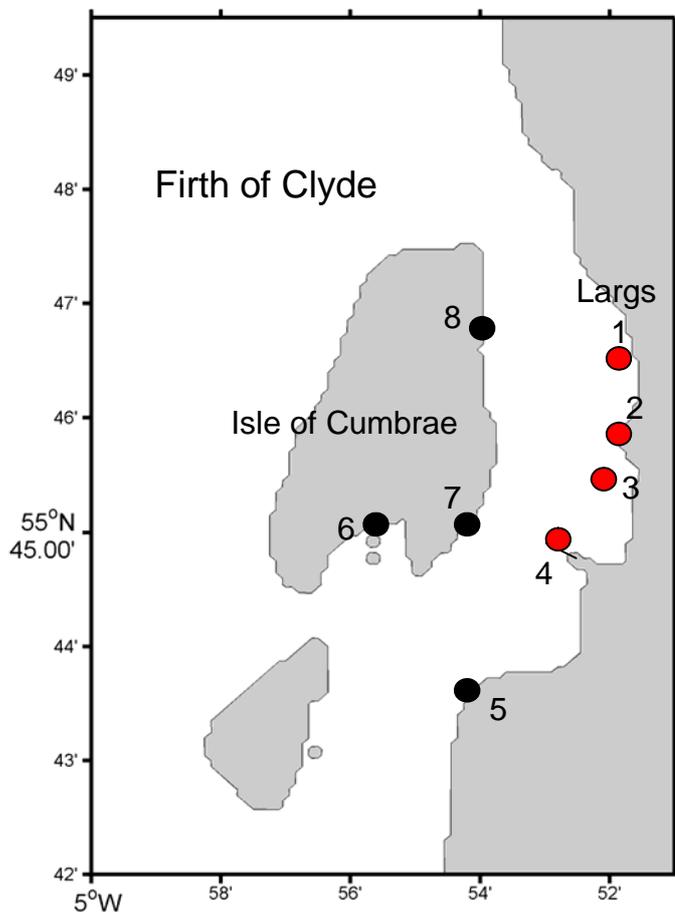


Figure 3.2 Locations of artificial structures surveyed around Largs. *D. vexillum* observed (red dots), not observed (black dots) 1. Largs Yacht Haven, 2. Fairlie Quay Jetty (Admiralty Pier), 3. Fairlie Quay moorings, 4. Clydeport jetty, 5. Hunterston power station pier, 6. Millport Pier, 7. UMBSM Keppel Pier, 8. Cumbrae Water Sports pier and pontoon.

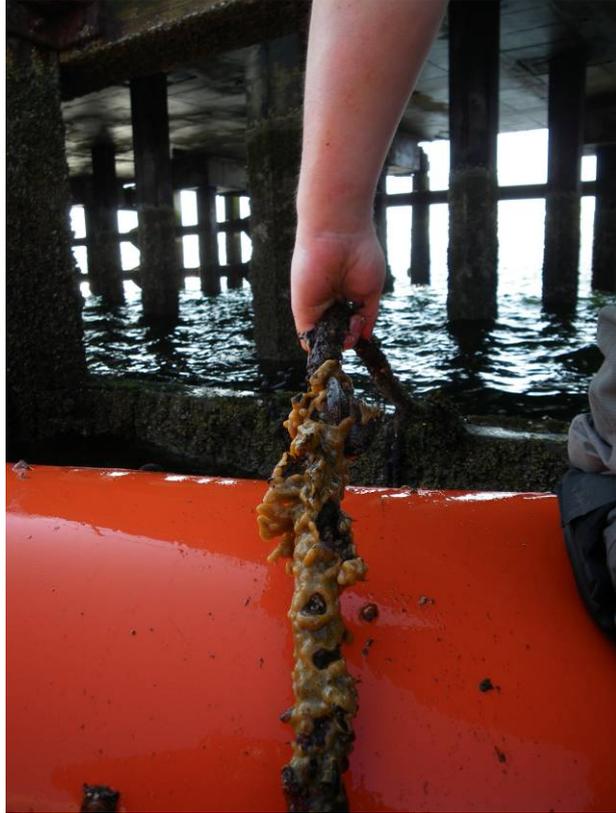


Photo 3.5 D. vexillum on a rope attached to Fairlie Quay Jetty (C. Beveridge, SAMS).



Photo 3.6 D. vexillum on piling of Fairlie Quay Jetty (C. Beveridge, SAMS).

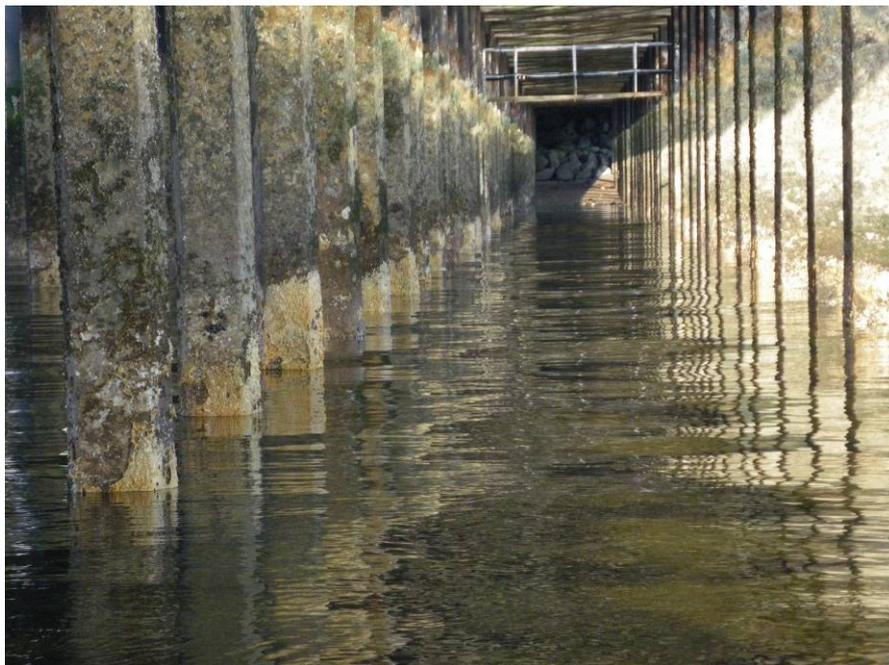


Photo 3.7 D. vexillum seen as creamy areas at the water line on the left hand pilings of Fairlie Quay Jetty (C. Beveridge, SAMS).



Photo 3.8 Clydeport Jetty viewed from the south (C. Beveridge, SAMS).



Photo 3.9 D. vexillum on piling of Clydeport Jetty (C. Beveridge, SAMS).



Photo 3.10 Underwater photograph of D. vexillum on piling of Clydeport Jetty (C. Beveridge, SAMS).



Photo 3.11 Underwater photograph of *D. vexillum* seen as a creamy patch on the left side of a ladder of Clydeport Jetty (C. Beveridge, SAMS).

3.4 Surveys of suitable natural substrates on the seabed around Largs

Video footage was obtained from all eleven sites (Table 3.1). *D. vexillum* was only found at Site 3, on the mooring chain of a navigation buoy (Photo 3.12).

Table 3.1 Description of ROV survey sites and presence/absence of *D. vexillum*

Site	Substrate	Maximum depth of dive (m)	Presence of <i>D. vexillum</i>
1	Sand with boulders and algal turf	11.4	N
2	Sand with boulders and algal turf	8.7	N
3	Mooring chain, heavily fouled	8.9	Y
4	Sand with boulders, brittlestar bed	8.4	N
5	Gravelly sand with occasional small boulders	8.3	N
6	Gravelly sand and pebbles	10.1	N
7	Sand	14.6	N
8	Sand	6.8	N
9	Sand with occasional boulders	8.8	N
10	Sand with pebbles, abundant <i>Laminaria saccharina</i>	5.1	N
11	Sand with boulders and abundant <i>Laminaria saccharina</i> , changing to sand with algal turf	5.9	N



Photo 3.12 Underwater photograph of *D. vexillum* on the mooring chain of a navigation buoy at Site 3 (SNH)

3.5 Clean-up of fouled items in Largs Yacht Haven

D. vexillum was found on a number of substrates throughout the marina. The highest density of material removed was from Pontoon AB which are the oldest pontoons and where the older and smaller vessels are kept. Pontoon JK had the highest proportion of colonised hanging material (Table 3.2).

Table 3.2 Number of items removed from the pontoons and the percentage of colonised material.

Pontoon	AB	CD	EF	GH	JK	LM	NP
Sites	35	12	8	14	8	6	12
Items	48	16	9	20	9	6	39
Colonised	21	9	3	11	8	1	13
% colonised	44	56	33	55	89	17	33

A total of 147 hanging items were removed from the pontoons. These ranged from short pieces of lightly fouled rope to tyres and heavily fouled ropes and settlement panels and included three anchor chains. Of the items removed, 65 were found to be colonised by *D. vexillum*. This represents 44% colonisation.

Colonies of *D. vexillum* were generally, but not exclusively, restricted to items which were hanging more than 1 m below the surface. Frequently, a band of kelp and mussels was found immediately below the surface. *D. vexillum* was not seen on kelp fronds.

Colonisation of piles, pontoon floats and hulls was not assessed; however, at low tide colonies were noted on several piles, notably on all but two of the piles on NP pontoon where the SAMS survey was limited by high tide. It should be noted that identification was from the surface without any viewing equipment.

Anecdotal evidence from staff indicated a familiarity with *D. vexillum* which had been seen on piles and on a number of vessels when lifted for cleaning. These sightings were not verified as being *D. vexillum*.

3.6 Additional non-native species

In addition to recording sightings of *D. vexillum*, the SAMS survey team recorded the presence of other non-native species observed during the survey (Table 3.3). Many of these sightings are recorded for the first time at the location specified, including *Corella eumyota* at Oban and Troon, *Heterosiphonia japonica* at Oban and Craobh Haven and *Codium fragile* subspecies *fragile* (previously known as *Codium fragile* subsp. *tomentosoides*) at Oban, Craobh Haven and Portavadie. Non-native species were not recorded in this survey at Dunstaffnage, Ardfern, Campbeltown, Portpatrick and Tarbert.

During the follow-up survey, *Corella eumyota* and *Botrylloides violaceus* (ID confirmation required) were seen at the base of a number of the pilings on Wemyss Bay Caledonian MacBrayne Pier (Photos 3.13 and 3.14).

Table 3.3 Location of additional non-native species found during the *D. vexillum* survey.

Survey Location	Species					
	<i>Heterosiphonia japonica</i>	<i>Codium fragile</i> subsp <i>fragile</i>	<i>Styela clava</i>	<i>Corella eumyota</i>	<i>Caprella mutica</i> *	<i>Tricellaria inopinata</i>
Dunstaffnage						
Oban	x	x		x		
Stranraer			X			
Portpatrick						
Troon				x	x	x
Clyde			X			x
Largs						
Ardfern						
Craobh Haven	x	x				
Tarbert						
Portavadie		x				
Campbeltown						

Note: Please refer to Ashton *et al.* (2006), Harries *et al.* (2007) and Dias *et al.* (2008) for a more comprehensive overview of non-native marine species in Scotland, as certain species, which have been previously found at some of these locations, were not found on this survey due to variations in their seasonal abundance and/ or difficulty in identification using solely morphological characteristics.



Photo 3.13 Corella eumyota at the base of a piling under Wemyss Bay Cal Mac pier. (C. Beveridge, SAMS).



Photo 3.14 Corella eumyota at the base of a piling under Wemyss Bay Cal Mac pier with in the centre a small patch of Botrylloides violaceus (ID confirmation required). (C. Beveridge, SAMS).

4 DISCUSSION

The presence of *Didemnum vexillum* in a small area of the Firth of Clyde, and its absence from all other locations surveyed both to the north and south of Largs, suggests a recent arrival of this species to Scotland. The fact that *D. vexillum* has not been found in previous annual surveys of marinas in Scotland indicates that this species may have been introduced in 2009. It is not known whether *D. vexillum* arrived first in Largs Yacht Haven and spread to the surrounding area, or whether it established outside the marina first and was then transported into it.

Since the initial discovery of *D. vexillum* in the Clyde, a management programme is being developed which is considering options for either attempting to eradicate this species before it spreads further, or trying to prevent further spread through containment measures.

4.1 Dispersal vectors

D. vexillum has most likely been spread globally by shipping, either as hull fouling or within the sea chests (Lambert, 2009). In New Zealand, the dispersal of this species was linked to the movement of a commercial barge (Coutts, 2002), in Ireland it has been linked to leisure craft and in France to commercial shipping (Minchin & Sides, 2006). In addition, subsequent localised dispersal has been linked to small craft, fouled aquaculture stock and equipment, and drifting and reattachment of dislodged fragments (Lambert, 2009).

The Clyde is a busy shipping area for both recreational and commercial vessels. In addition, shell- and fin-fish aquaculture is a major industry in this region, with supply vessels either based within or moored adjacent to a number of marinas. The expansion of the leisure craft industry over the last few years has been rapid and this has been particularly evident on the west coast of Scotland, with the construction of new marinas and the expansion of existing ones. It is possible, therefore, that *D. vexillum* was accidentally introduced to the marina, or to the surrounding area, on the hull of a vessel or vessels.

Largs Yacht Haven is one of the largest marinas in the Clyde, currently providing about 700 berths, which can be accessed at all states of the tide. The management of Largs Yacht Haven follows environmental good practice, with most resident boats being removed from the water for hull cleaning on an annual basis using a wash-down facility that prevents the run-off of waste back into the sea. However, this alone cannot guarantee that non-native species will not be transported on the hulls of incoming vessels, either recreational or commercial.

D. vexillum is not likely to have arrived in the region by natural means of dispersal, as the free-living larval stage typically only lasts for a few hours (Minchin & Sides, 2006). Since its arrival, the dispersed nature of *D. vexillum* throughout the marina may be attributed to natural spread of the larvae or detached fragments by tidal or wind-driven currents generated within the break-walls of the marina following the initial introduction. Dispersal of *D. vexillum* from Largs Yacht Haven to the surrounding area, or vice versa, may have been by natural dispersal or by human activity.

To minimise the spread of *D. vexillum* throughout Scottish waters action is urgently required to raise awareness of this species and to introduce guidelines on hull cleaning frequency and disposal of fouling organisms in both the recreational and commercial marine sectors.

4.2 Implications for future spread

D. vexillum can grow extremely rapidly and form either pendulous colonies which can extend over 60 cm in length (Minchin & Sides, 2006) or extensive carpet-like growth forms extending over square kilometres of seabed, as reported on the Georges Bank (USGS, 2010). This species can over-grow a wide variety of natural substrata, including commercially valuable shellfish species, and poses a considerable risk to marine habitats of conservation value (Minchin & Sides, 2006). However, in this study, *D. vexillum* was not found on the seabed, even close to the areas where it was growing abundantly on artificial structures.

D. vexillum can overgrow a range of artificial substrata, including vessel hulls, fin-fish cage netting, ropes, marina pontoons, scallop cages, creels and 'keep cages' (C. Beveridge, pers. obs.). This can have serious consequences for the aquaculture industry (Coutts, 2005), a major employer on the west coast of Scotland. In Largs Yacht Haven, *D. vexillum* was found over-growing a wide variety of sessile species, including the mussel *Mytilus edulis*, which is commercially grown on the west coast of Scotland, and artificial substrata including ropes, plastic settlement panels and keep-cages or creels. Interestingly though, it was only found on three pontoon floats in this marina, suggesting that a physical factor, such as reduced salinity in the surface waters may be preventing the settlement of *D. vexillum* at this location on these floats (C. Beveridge, pers. obs.).

In New Zealand, the environmental and economic damage caused by *D. vexillum* has led to significant research into the management of this species following introduction (Coutts & Sinner 2004) and potential control methods (Denny, 2008). A rapid response eradication programme in Holyhead Harbour, North Wales is also currently underway (Holt *et al.*, 2009).

Over the past few years, it has been evident that once invasive species have become established in the marine environment, attempting to control them is extremely labour intensive and costly and that the impact on non-target species can be significant. As a result of this survey and previous survey work (Ashton *et al.*, 2006), the Largs coast is the only region where *D. vexillum* has been found in Scotland to date. Targeting this location and eradicating this initial introduction before establishment and further spread is allowed to occur is, therefore, critical in safeguarding Scottish native biodiversity and the aquaculture industry from the impacts of *D. vexillum*.

4.3 The importance of regular monitoring

D. vexillum was first identified in Largs Yacht Marina as part of a regular survey programme. A number of non-native species were recorded for the first time in a small number of locations during this survey, highlighting the importance of having a team of specialists trained to identify or to recognise a potential non-native species *in situ* and of having a regular monitoring programme in place. Many of the species identified are unlikely to pose a serious economic or environmental risk, unlike *D. vexillum*; however, it is still important to monitor their spread and to use their presence as an indicator of potential 'high risk' sites of non-native species introduction.

5 CONCLUSIONS

- *Didemnum vexillum* was only found in one out of the 12 marinas surveyed in south-west Scotland in February 2010: Largs Yacht Haven.
- Of the 12 additional sites surveyed in the vicinity of Largs Yacht Haven in April 2010, *D. vexillum* was observed at three locations: Fairlie Quay Jetty, Fairlie moorings and Clydeport Jetty.
- *D. vexillum* was well established throughout Largs Yacht Haven at a water depth between ~1 and 5 m and typically occurred on pilings, ropes, plastic cables, tyres, keep cages and on other marine organisms including the mussel *Mytilus edulis*, barnacles and the solitary tunicate *Ciona intestinalis*.
- *D. vexillum* was well established at Fairlie Quay Jetty at the low water level on ~70% of pilings. Fairlie moorings had one record and Clydeport had three records.
- *D. vexillum* was not found on suitable natural substrates on the seabed in the vicinity of Largs, suggesting a preference for artificial structures and/or vertical substrates.
- It is possible that *D. vexillum* was introduced to the marina, nearby jetties and moorings via hull fouling on vessel(s) during 2009.
- As an initial step in management of this species, a total of 147 hanging items were removed from the pontoons in Largs Yacht Haven. These ranged from short pieces of lightly fouled rope to tyres and heavily fouled ropes and settlement panels and included three anchor chains. Of the items removed, 65 were found to be colonised by *D. vexillum*.
- If allowed to disperse from this site, *D. vexillum* poses a considerable risk to the Scottish aquaculture industry and to marine habitats of conservation value.
- Increased awareness of *D. vexillum* and clear guidelines on how to minimise the spread of this species must be urgently produced in close collaboration with the commercial and recreational maritime sector.

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