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1 author:

Stefan Kraan
The Seaweed Company

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Sargassum muticum (Yendo) Fensholt in Ireland: an invasive species on the move

Stefan Kraan

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Abstract The invasive marine macroalga *Sargassum muticum* was recorded from Kilmore Quay, Co. Waterford, for the first time in the Republic of Ireland in 2001. It was found at several other places in that year and in subsequent years. An intensive survey was carried out from April 2003 to November 2003 to map the geographical distribution and spread of this invasive brown macroalga, and data on distribution were collected in subsequent years through 2006. This study indicated that *S. muticum* most probably arrived in the early or mid 1990s and has spread all around the Irish coastline colonising Co. Donegal for the first time in 2006. The results indicate that spreading is facilitated by boating and perhaps via shellfish transport. A rough rate of spread of 2–3 km year^{-1} has been calculated within one bay and for the Irish coastline of about 54 km year^{-1}. Observations showed that *S. muticum* has been found growing in seagrass beds and in rock pools, which might have serious consequences for the biodiversity in rock pools and for the protective status of seagrass habitats. It is recommended that monitoring of *S. muticum* should continue, especially in areas of high amenity value and economic importance in order to observe possible effects on local flora and fauna, aquaculture, the seaweed industry and tourism.

Keywords Geographical distribution · Ireland · Point introduction · Rock pools · *Sargassum muticum* · Seagrass beds · Spreading rate · Transport · Vector

S. Kraan (✉)
Irish Seaweed Centre, Martin Ryan Institute,
National University of Ireland, Galway,
Galway, Ireland
e-mail: Stefan.kraan@nuigalway.ie

Introduction

Sargassum muticum (Yendo) Fensholt was recorded for the first time in the Republic of Ireland at Kilmore Quay in August 2001 (Fahy 2001). Kilmore Quay is a popular yachting harbour attracting yachts from France and the United Kingdom. It was subsequently found at Rath Strand, Kenmare River, Co. Kerry (Winder 2002); Cashel Bay, Co. Galway (Loughnane and Stengel 2002); and Drum Cliff Bay, Co. Sligo (Callagher, personal communication, 2002; Fig. 1, see names marked with a black asterisk). It is important to note that these plants were attached, indicating the presence of established populations.

Sargassum muticum was endemic to Japan prior to 1944, when it was introduced to Pacific Canada (Ribera and Boudouresque 1995). In the last 20–40 years, the geographical range of this species has spread dramatically. It was discovered for the first time in Europe in 1973 off the Isle of Wight in Britain (Farnham et al. 1973; Farnham and Jones 1974) and was then found in the Mediterranean by 1980 (Ribera and Boudouresque 1995). Moreover, it was found in the Isles of Scilly, along the entire English Channel coast (Hiscock and Moore 1986) and the east coast north to Suffolk; however, the Norfolk population appears to be no longer extant (Critchley et al. 1983). Attached specimens were found in Strangford Lough, Northern Ireland, in 1995 (see Fig. 1 marked with ©) and in north Cornwall in 1991 (Boaden 1995). Elsewhere in Europe it is known from the Mediterranean and along the North Sea and Atlantic coasts of Portugal, Spain, France, Belgium, the Netherlands, Germany, Denmark, southern Norway and Sweden (Critchley et al. 1983; Kornmann and Sahling 1994; Rueness 1989). In Denmark the first specimen of *S. muticum* was found in 1984 in Nissum Bredning, Limfjorden (Christensen 1984). Since then it

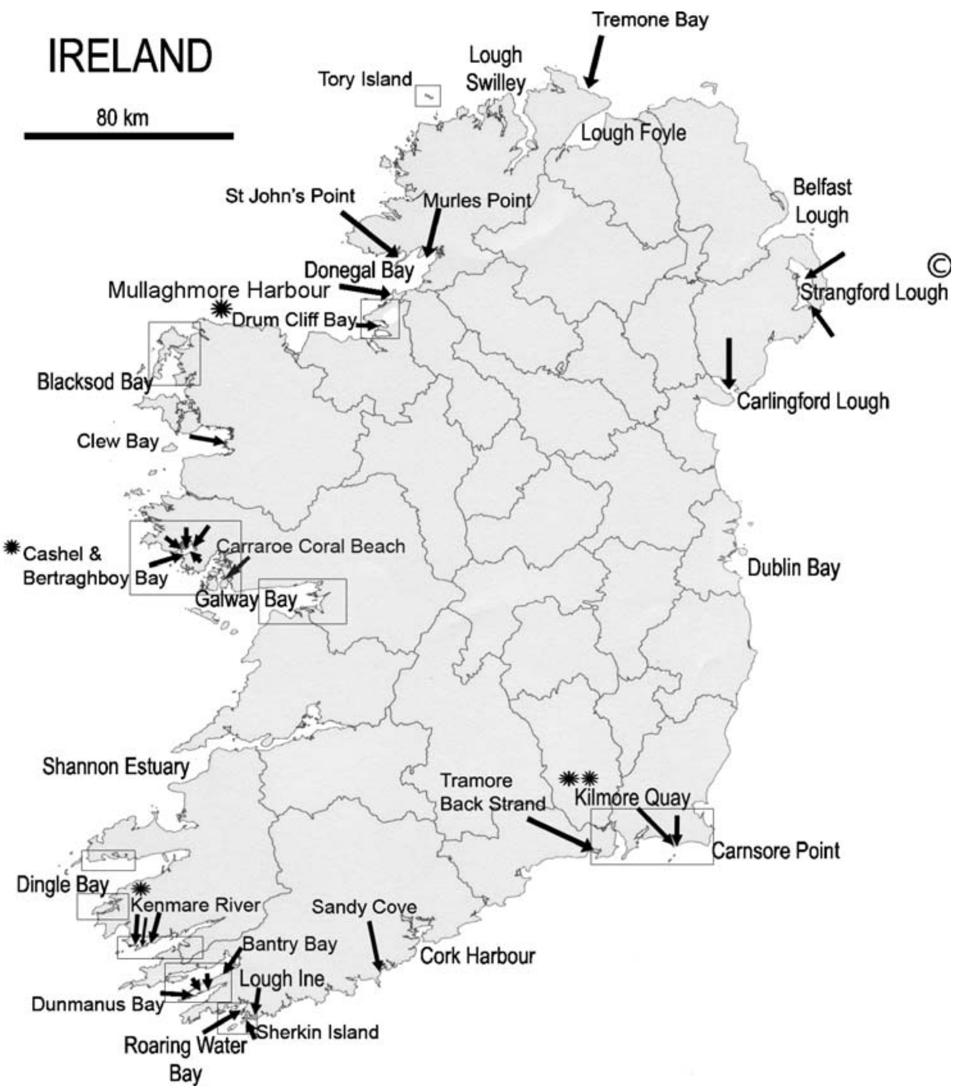

Fig. 1 Records of *Sargassum muticum* in Ireland since its discovery in Strangford Lough, Northern Ireland, in 1995 (marked with ©) and subsequently for the first time in the Republic of Ireland in Kilmore Quay in 2001 (marked with two black asterisks) and other places later that year (marked with one black asterisk). Records have been collected up to May 2007. Boxed areas were surveyed in 2003. Arrows indicate established beds or attached plants of *S. muticum*

has spread throughout the fjord, where it is now the dominant macroalga. Remarkably, it was estimated that *S. muticum* at the current rate of spreading would arrive in Irish coastal waters during the mid 1980s. However, it took more than 15 years to establish itself in Irish waters.

It is not clear by what mechanism *S. muticum* was introduced into Europe; however, the most likely vectors were out-growing of imported oysters or boating activities (Farnham and Jones 1974; Ribera and Boudouresque 1995). According to Critchley et al. (1990), it was an associated unintentional introduction with commercial introductions of oysters from the Canadian state of British Columbia or Japan to France. Spreading from northern France is presumed to have occurred by natural means. Propagules or fragments may be transported in ballast water, on ships' hulls and by rafting or floating of entire plants or detached fragments. Marginal dispersal (up to 30 miles) is most likely to occur by the latter method (Farnham et al. 1981). The spread along the English south coast was calculated at about 30 km year^{-1} and along the northwest American coast at an average rate of about 60 km year^{-1}, mostly by drifting of fertile adult fragments (Farnham et al. 1981). In Denmark a colonisation rate of 15 km year^{-1} was found in Limfjorden indicating that the colonisation rate is strongly dependent on factors such as currents, prevailing winds and geography (Stæhr et al. 2000). *Sargassum muticum* can outcompete local species due to its fast growth rate and can reproduce within the first year of life. It has a diplontic life cycle and, being monoecious, can fertilize itself (Yendo 1907; Jensen 1974). Fertilized embryos remain attached to the receptacle until they develop tiny, adhesive rhizoids. At this point they are released and recruit to the substratum in close proximity to the parent plant (Deysher and Norton 1982).

Reasons for successful invasions

Sargassum muticum possesses characteristics of both r- and K-selected species, such as a high growth rate of up to 4 cm day^{-1} (r: Norton 1976; Rueness 1989; Arenas et al. 1995), large propagule production (r: Norton 1976; Rueness 1989), high thallus differentiation (K: Jensen 1974) and long lifespan (K: Critchley 1981). Individuals of *S. muticum* have the highest biomass in July-August (Wernberg et al. 2001). Fertile receptacles, which are cast off during the summer months, are able to float and can survive for up to 3 months (Farnham et al. 1981). A single branch is capable of producing a large progeny. Adult plants are tolerant of a wide range of salinities and temperatures (−1 to 25°C), nevertheless the fertilization process and small germlings seem to be sensitive to low salinities (Steen 2004). The combination of these factors is thought to be the reason for its successful invasion of American and European waters (Hales and Fletcher 1989; Rueness 1989).

Effects on the environment and commercial interests

According to Farnham and Jones (1974) *S. muticum* can be a nuisance, both economically and ecologically. It causes the physical displacement of native species by over-growing and shading underlying species. It has the potential drastically to alter the ecosystem of shallow coastal waters and rock pools by out-competing other species and reducing the overall (seaweed) biodiversity (Critchley et al. 1986). There has been documented replacement of *Saccharina latissima* (Linnaeus) C.E. Lane, C. Mayes, Druehl & G.W. Saunders and *Zostera marina* Linnaeus at Grandcamp in Normandy on the French Atlantic coast (Givernaud et al. 1991), impacts on other algae and overall biodiversity at the American Pacific coast (Britton-Simmons 2004) and decrease in cover of several indigenous species belonging to the genera *Laminaria* J.V. Lamouroux, *Fucus* Linnaeus, and *Codium* Stackhouse indicating competitive displacement through competition for hard substrate and light (Stæhr et al. 2000).

In Britain, *S. muticum* has been found growing in rock pools and channels and in eelgrass beds (Critchley et al. 1986; Raines et al. 1992). Apparently, *Halidrys siliquosa* (Linnaeus) Lyngbye can be displaced by *S. muticum* as the dominant species (Raines et al. 1992; Stæhr et al. 2000). Withers et al. (1975) reported a rich epiphytic community associated with *Sargassum* collected from the east Solent, United Kingdom, suggesting that native epiphytic species are not particularly affected. *Sargassum muticum* has been responsible for fouling fishing gear and boat propellers (causing boating accidents), as well as blocking intake pipes (aquaculture) and has been reported to interfere with recreational use of waterways, particularly when it becomes detached from holdfasts and floats off forming large masses (Farnham 1980; Critchley et al. 1986). It is also a fouling organism on oyster beds and a nuisance to commercial fishermen, fouling their nets and 'stealing' colonised oysters by rafting (Critchley et al. 1986).

Eradication

The eradication of this species in British waters has been attempted but has failed. In common with almost all other marine invaders, *S. muticum* cannot be eradicated, although it can be controlled by seasonal harvesting in problem areas such as shellfish grounds and shallow channels frequented by small motor vessels. Removing *Sargassum* by hand is extremely time-consuming and needs to be repeated, probably indefinitely (Farnham 1980). Removal by trawling, cutting and suction has also been tried. Chemical methods using herbicide have been tried but failed due to lack of selectivity and the large doses needed. Small germlings are consumed by molluscs and amphipods but this seems to have no restrictive effect on *S. muticum*. Whatever method is used, the alga always quickly regrows, and effective methods for its permanent removal have not been found, although the preferred method is cutting and suction (Farnham et al. 1981; Critchley et al. 1986; Schaffelke et al. 2006).

The recent arrival of *S. muticum* on shores in the Republic of Ireland has initiated an investigation into the current distribution of this brown invasive macroalga in Ireland. The aim of this investigation is to determine the present status, distribution and invasive capability of *S. muticum* on the north, west and south coasts of Ireland.

Materials and methods

Sargassum survey areas and methodology

Based on records of *S. muticum* in 2001 and 2002, Cashel Bay, Co. Galway; Killmore Quay, Co. Waterford; Kenmare River, Co. Kerry; and Drum Cliff Bay, Co. Sligo, and areas in close proximity to these bays were chosen for surveying and are marked with square boxes in Fig. 1. Surveying took place by foot in the lower intertidal zone at low water, and along drift line at high water, by kayak at various stages of the tide spanning intertidal to subtidal, and by snorkelling or SCUBA diving at various stages of the tide spanning intertidal to subtidal. Names of surveyors, dates and places were recorded together with a site description and other general information such as bottom substrata and marine flora. Drift plants of *S. muticum* were noted, and attached plants were recorded using a GPS (Magellan, Meridian Marine) together with Map Send BlueNav Charts (Thales

Table 1 Bays and inlets where *S. muticum* was found during the survey and in the subsequent years 2004–2006 together with their GPS coordinates

Place	County	GPS	Bed or individual plants	Density per m^2	Survey method	Activity	Reference
Inner Cashel Bay	Co. Galway	N53°25′01″ W9°48′67″ to N53°24′87″ W9°48′17″	B	3	K	LF, F, Y	Irish Seaweed Centre 2003
Middle Cashel Bay		N53°24′97″ W9°49′72″ to N53°24′81″ W9°48′97″	B	3–5	K, S	LF, F, Y	Irish Seaweed Centre 2003
Outer Cashel Bay		N53°23′82″ W9°50′68″	15 over 300 m	< 0.1	OF	LF, F, Y	Irish Seaweed Centre 2003
		N53°24′06″ W9°51′71″	40 over 100 m	< 0.1			
		N53°23′25″ W9°51′88″ to N53°23′55″ W9°52′73″	25 over 900 m	< 0.1			
Blackhaven Bay		N53°23′81″ W9°53′37″	B	0.2	K	LF, F	Irish Seaweed Centre 2003
		N53°23′70″ W9°53′17″	B	3			
		N53°23′28″ W9°53′63″	B	1			
Roundstone Bay		N53°23′31″ W9°54′32″	FI	-	OF	Y, LF F	Irish Seaweed Centre 2003
Illaunaknock east of Glinsk Pier		N53°23′04″ W9°48′67″	B	5	S	LF, F	Irish Seaweed Centre 2003
Leitir Árd Quay, Inishtreh Aound		N53°21′92″ W9°53′48″	B	3	S	LF	Irish Seaweed Centre 2003
Carraroe coral beach		N53°14′92″ W9°37′80′	FI	5	OF	RP	Stefan Kraan, pers. obs., 2007
Reen Point Loughaun Pier, Bantry Bay	Co. Cork	N51°38′75″ W9°34′97″	B	6–8	S	A	Irish Seaweed Centre 2003
Farranamagh, Kilcrohan, Dunmannus Bay		N51°34′65″ W9°41′20″	B	3	D	LF, Y	P. Whelan, pers. obs., Botany Dept. University College Cork, 2002
Kitchen Cove Dunmannus Bay		N51°35′73″ W9°38′25″	FI	-	S	LF, F	Irish Seaweed Centre 2003
Carriglea Rock, Dunmannus Bay		N51°36′62″ W9°35′29″	RP	7	OF	-	Irish Seaweed Centre 2003
Sherkin Island, Roaring Water Bay		N51°28′60″ W9°24′80″	MI	-	OF	LF, Y	Marie Mahon, pers. comm., 2004
White Hall, Roaring Water Bay		N51°31′15″ W9°25′60″	FI	-	K	A	Irish Seaweed Centre 2003
Lough Hyne		N51°29′80″ W9°17′80″	FI	-	-	Y	Simkanin 2004
Sandy Cove, Kinsale Harbour		N51°40′54″ W8°31′33″	B	3	OF	Y	Irish Seaweed Centre 2005
Rath Strand, Caher Daniel	Co. Kerry	N51°45′30″ W10°06′09″	RP	60	K	Y	Irish Seaweed Centre 2003
Rath Slip, Caher Daniel		N51°45′90″ W10°04′78″	B	1–2	K	Y, LF	Irish Seaweed Centre 2003
West Cove		N51°46′10″ W10°03′20″	B	3	K	Y, LF	Irish Seaweed Centre 2003
Rosses Point, Yachting club	Co. Sligo	N54°18′36″ W8°34′52″	FI	-	S	Y	Irish Seaweed Centre 2003
Mullaghmore Harbour, Donegal Bay		N54°27′85″ W8°26′55″ to N54°27′70″ W8°26′45″	B	1–5	OF	Y, LF	D. Minchin, Marine Organism Investigations, 2005
Ross Laher, Kilmeena, Clew Bay	Co. Mayo	N53°50′80″ W09°34′20″	MI	On oysters and trestle	OF	A	Padraig Gannon, Croagh Patrick Seafoods, 2003
Killmore Quay, Forlorn Point	Co. Waterford	N52°10′29″ W06°35′47″ to N52°10′63″ W06°33′56″	B	3–5	OF	Y, LF, F	Irish Seaweed Centre 2003

Calingford Marina	Co. Louth	N54°03′11″ W06°11′38″ to N54°03′12″ W06°11′40″	FI	-	OF	Y	D. Minchin, Marine Organism Investigations, 2005
East Bay, St John's Point	Co. Donegal	N54°32′92″ W08°27′51″	B	3	S	LF	Julia Nunn, Ulster Museum and Botanic Gardens, Belfast, 2006
Murles Point	Co. Donegal	N54°34′12″ W08°17′64″	MI	-	RP	LF	Julia Nunn, Ulster Museum and Botanic Gardens, Belfast, 2006
Tremone Bay, Inishowen Peninsula		N55°16′32″ W07°04′19″	RP	-	S	F, LF	Julia Nunn, Ulster Museum and Botanic Gardens, Belfast, 2006

A Aquaculture, *B* beds, *D* dredging, *F* fisheries, *FI* few individuals, *MI* many individuals but not beds, *K* kayak, *S* snorkelling/diving, *Y* yachting, *LF* lobster fisheries, *OF* on foot, *RP* rock pool

Navigation, UK, 2002) and software (version 4.0). The site and *S. muticum* plants (drift and attached) were photographed using a digital camera.

Wind and current profiles around Ireland

Prevailing wind data and seawater current profiles were obtained from the Irish Marine Institute (Marine Institute 2006), showing a southwesterly wind as the prevailing wind 28% of the time and a northwesterly wind 23% of the time. The water circulation in this area is dominated by the poleward-flowing slope current. This persists throughout the year north of Porcupine Bank and is stronger in the summer. South of the bank the current is present in the winter months, but breaks down in the summer, when flow becomes complex. There is also a weaker current flowing north from Brittany and splitting east and west along the Irish coast. In general there is a current flowing clockwise around Ireland.

Biomass and extent of the beds at Kilmore Quay, Co. Waterford

A sub-sample of plants were measured for length (in cm) and wet weight (in grams) where large beds were established, using a measure tape and a hanging balance respectively. A total of 29 attached plants were measured at Cashel Bay, Connamara, Co. Galway (N53°25.106′ W9°48.732′) on the 7th of August 2003; 5 attached plants at Rath Slip, Rath Strand, Kenmare River, (N51°45.432′ W10°05.728′) on the 12th and 13th of August 2003; and 8 attached plants at Cloonile Bay, Connamara, Co. Galway (N53°23.699′ W9° 53.174′) on the 8th of August 2003. A quadrat was used to determine the number of plants per square meter. With the average wet weight per plant and number of plants per square meter, a standing stock for a given area could be calculated for August. A study by Wernberg et al. (2001) showed that individuals of *S. muticum* had a significantly higher biomass in July-August than at any other time of the year. One area with an extensive large bed was at Kilmore Quay. Biomass for August was calculated for Kilmore Quay using the surface area of the bed, the number of plants per square meter and the average wet weight of the plant measurements.

Results

Distribution and length and wet weight measurements of *S. muticum* in Ireland

Areas with attached *S. muticum* found during the survey in 2003 and in the subsequent years 2004, 2005 and 2006 are shown by arrows in Fig. 1. Additional data are presented in Table 1. The overall distribution map of *S. muticum* in Ireland (Fig. 1) shows that the species has spread all around the island of Ireland (excluding the sandy beaches at the east coast between Carlingford Lough and Carnsore Point, as these beaches offer no substrata for seaweeds to grow on), with the latest records from Lough Hyne and Sandy Cove, Co. Cork; St John's Point and Tramone Bay, Co. Donegal; and Carraroe Coral Beach, Co. Galway (Fig. 1). Once established, the alga starts spreading from the original point of introduction. Average length and weight measurement were taken of *S. muticum* beds in three bays in August 2003 (Table 2). The smallest plant was 50 cm and the tallest plant 470 cm. The lightest plant was 75 g and the heaviest was 2,300 g wet weight.

Biomass estimation for the bed at Kilmore Quay

The area from the eastern harbour wall of the marina at Kilmore Quay exposed a large scattered *S. muticum* bed with 3 plants/m^2. Plants of up to 4 m were commonly found. The most easterly *S. muticum* plants were found at N52°10′63″ W6°33′56″ and were attached on rocks within a seagrass bed. The bed at Kilmore Quay had a calculated surface area of 234,600 m^2 containing approximately 700,000 plants. The standing stock of the Kilmore Quay *S. muticum* bed for the month of August using the average weight measurements (Table 2) of 696±501 g per plant is estimated to be 487 t wet weight with a minimum of 137 t and a maximum of 838 t. This large, well-established population indicates that it has probably been present since the early 1990s and most probably has acted as the source for further distribution around the Irish west coast via boating.

Table 2 Average length (cm) and wet weight (g) with standard deviations (SD) of *S. muticum* plants sampled at Cashel Bay, Cloonile Bay and Kenmare River in August 2003

Sample area and date		*n*	Average	SD
Cashel Bay, Connamara, Co. Galway; 7 August 2003	Length	29	168.2	111.3
	Wet weight	29	383.1	321.5
Cloonile Bay, Connamara, Co. Galway; 8 August 2003	Length	8	235	71.5
	Wet weight	8	715.6	467.1
Rath Slip, Rath Strand and Westcove, Kenmare River, Co. Kerry; 12–13 August 2003	Length	5	162	168.6
	Wet weight	5	760	892.8

Rate of spreading

One bay was suited for calculating the rate of spreading, Cashel Bay, Connamara, Co. Galway; however, the following assumptions had to be made: (1) records from 2001 represented a point introduction, and (2) the place of introduction was only the place where the alga first was recorded and that spreading originated from the point of introduction. In Cashel Bay, the record dates from 2001 and large fertile plants were found indicating that these plants have arrived at least 1 year before in 2000. Assuming that the introduction at Cashel Bay was a point introduction by boat or yacht it is possible to calculate the rate of spread. The distance from the boathouse (first place of discovery in 2001) in middle Cashel Bay to Leitir Árd (survey observation of 2003) is approximately 7.5 km indicating a rate of spreading of 2–3 km year^{-1}. A rate of spreading around the coast has been calculated as well using the record from Cashel Bay from 2001 and the arrival in the east bay of St John's Point, Co. Donegal, in 2006 (which in previous surveys of 2003 and 2004 had no *S. muticum* established). The distance between Cashel Bay and St John's Point is about 270 km by sea, giving a rate of spreading of about 54 km year^{-1}.

Discussion

The records and survey data of this study show that *S. muticum* has spread all around the Republic of Ireland within 5 years of its discovery at Kilmore Quay in 2001. The extent of the beds, e.g., Farramanagh, Bantry Bay and Kilmore Quay, strongly suggests that these beds were established at least several years ago, most probably in the early 1990s. This would agree with the discovery of *S. muticum* in Strangford Lough, Northern Ireland, in 1995. It is therefore difficult to establish a precise introduction date and a rate of spreading as records showed up simultaneously at the west and south coast in 2001. Comparison with spreading rates of *S. muticum* found in other countries shows that in Ireland the spreading rate along the coastline is similar to that of the northwest American coastline and almost twice as fast compared to the English coast (Farnham et al. 1981). The spreading rate calculated for Bertraghboy Bay, Co. Galway, is five times slower compared to the Limfjorden, Denmark, indicating that the colonisation rate is strongly dependent on factors such as currents, prevailing winds and geography (Stæhr et al. 2000).

Of some concern is the establishment of *S. muticum* in seagrass beds at Kilmore Quay. *Sargassum muticum* is known to replace certain native macroalgae and is able to replace seagrass beds (Givernaud et al. 1991; Wernberg et al.

2001; Britton-Simmons 2004). Seagrass beds are protected as part of a specific habitat under Habitats Directive 1992. Moreover, seagrass beds are often part of a habitat that occurs in a number of areas proposed as Special Areas of Conservation (SACs) under the EC Habitats Directive. Recent initiatives arising from the EU Habitats Directive and the Convention on Biological Diversity have led to seagrass habitats being specifically targeted for conservation and restoration and include provisions requiring measures to prevent the introduction of, or to control the spread of, non-native species, especially those that threaten native or protected species (Wynne et al. 1995).

Once *S. muticum* has established itself in an area, it can affect the surrounding biodiversity. In Denmark the invasion of *S. muticum* started in 1984 and has changed the macroalgal community structure to a less complex system with fewer species overall and fewer species of intermediate dominance (Stæhr et al. 2000; Wernberg et al. 2001).

Britton-Simmons (2004) concluded from his experimental field data from San Juan Islands, Washington, that *S. muticum* competes with native canopy and under-storey algae and has a negative, indirect effect on the native herbivore sea urchin *S. droebachiensis*. Moreover, *S. muticum* reduced native algal biodiversity and decreased the growth rate of the native kelp *Laminaria bongardiana* Postels & Ruprecht. *Sargassum muticum* has been present in this area since the 1950s.

In Portugal and Spain, the most southerly distribution limit of *S. muticum* in Europe, sheltered tide pools form a specific habitat which *S. muticum* is able to colonise. Recently colonised rock pools appear to be completely dominated by *S. muticum*, out-competing other macroalgal species (Engelen et al. 2003; Arenas et al. 2003).

Sargassum muticum is a relatively new arrival in Ireland and possible effects on the biodiversity and surrounding fauna and flora may be difficult to establish, although it has been observed in seagrass beds and rock pools. The first record at Rath Strand in 2001 described a few plants in a rock pool. This survey revealed 65 plants in the same rock pool. A continuous monitoring program may reveal the possible effects this may have. It is possible that *Halidrys siliquosa*, a common species of intertidal rock pools, could be out-competed and might disappear from rock pools altogether as seen in Portugal (Engelen et al. 2003; Arenas et al. 2003). While this is speculative it indicates that proper studies should be conducted on the effect of *S. muticum* in rock pool colonisation and seagrass bed invasions. In general, non-native species may displace native organisms by preying on them or out-competing them for resources such as food, space, nutrients and light. In some cases this has led to the elimination of indigenous species from certain areas (Britton-Simmons 2004).

In Cashel Bay, it appears that *S. muticum* occupies a niche which is not used by other macroalgae. It grows below the *Fucus serratus* Linnaeus zone on small rocks on a muddy bottom, sometimes with *Saccharina latissima*. The area *S. muticum* occupies is most probably too deep for other intertidal algae to occupy and too sheltered for *Laminaria* species like *L. digitata* (Hudson) J. V. Lamouroux and *L. hyperborea* (Gunnerus) Foslie to settle.

The invasion of *S. muticum* in Ireland may perhaps change the intertidal flora make-up and may have implications for seaweed harvesters in rural areas, affecting their traditional way of life and their heritage. Moreover, it might have an effect on seaweed processors that harvest *Ascophyllum nodosum* (Linnaeus) Le Jolis for the horticulture, animal feed, alginates and biotechnology industries, as *S. muticum* may be harvested with the commercial harvested alga thus lowering the value of the processed end-product.

Sargassum muticum was often found in conjunction with mooring areas, anchorage sites and pontoons, indicating that the most likely vector for distribution in Irish waters is by boat and not oyster aquaculture, although it is often difficult to pinpoint a pathway for a specific introduction (Schaffelke et al. 2006). It is possible that yachts arriving from colonised areas within Ireland and from the United Kingdom and France may be responsible for transporting this species to new areas with established marinas or anchorage sites by carrying *S. muticum* on their hull, rudder, fishing gear or anchor chain (for an extensive review on pathways, see Schaffelke et al. 2006). An example is the marina in Mullaghmore Harbour, Co. Sligo. This marina was surveyed in August 2003, and no plants of *S. muticum* were encountered. The harbour was surveyed again in August 2005, and large beds were encountered. This indicates that, in areas free of *S. muticum*, fragments may drift or be brought in by boat and establish beds within 2 years.

At present *Sargassum muticum* has established itself all around the Irish coast, and it is recommended that monitoring continue in order to observe possible effects on local flora and fauna. Specifically seagrass beds and rock pool communities are of interest as in other studies it has been shown that effects take place in these specific habitats.

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