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Research article

European expansion of the introduced amphipod *Caprella mutica* Schurin 1935

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Abstract

The amphipod *Caprella mutica* is one of the most rapidly invading species in Europe and has extended its range throughout North Sea and Celtic Sea coasts and the English Channel in less than fourteen years. It was first described from sub-boreal areas of north-east Asia in 1935 and has since spread to both northern and southern hemispheres. The first European record was from The Netherlands in 1994. Since then it has spread within the North Sea and later to the west coast of Scotland and to Ireland. *C. mutica* is frequently associated with man-made structures and is found in abundance on boat hulls, navigation/ offshore buoys, floating pontoons and aquaculture infrastructure. It is highly likely that its dispersal is associated with vessel movements whilst attached to hull fouling. This species is expected to colonise the west coasts of France and Spain and offshore islands in the north-east Atlantic.

Key words: *Caprella mutica*, Europe, caprellid, crustacean, distribution, biological invasion

Introduction

The caprellid amphipod *Caprella mutica* Schurin 1935 (Figure 1) is indigenous to sub-boreal waters of north-east Asia (Peter the Great Bay, Vladivostok, Russia) and was subsequently identified in the neighbouring Possjet Bay, Japan (Vassilenko 1967) and Akkeshi Bay, Japan (Arimoto 1976). The first reports of *C. mutica* outside its native habitat were from the Pacific and Atlantic coasts of North America in the 1970s (Carlton 1979) and 1980s (Marelli 1981, Cohen and Carlton 1995) and a recent review of its global distribution has shown that within 40

years this species has spread throughout the northern hemisphere and it has recently been found for the first time in New Zealand (Ashton et al. 2007a).

C. mutica is one of the largest caprellid amphipods, mature males attain body lengths of up to 50 mm (Nishimura 1995). Females are highly fecund, producing their first brood approximately 53 days post-hatching at an average body length of 8.5 mm and at a seawater temperature of 13–14°C (Cook et al. 2007). Each female has an average of two sequential broods released at approximately 20 day intervals. The maximum number of recorded hatchlings produced by a single female at a seawater temperature of 13.0±0.5°C is 82. Juveniles typically emerge from the brood pouch at a body length of approximately 1.3 mm (Cook et al. 2007). *C. mutica* is able to survive for up to 20 days without additional food under laboratory conditions (Cook et al. 2007) and tolerates temperatures of < 2°C to 28°C and salinities down to 19 psu over a short (48 h) exposure period (Ashton et al. 2007b). *C. mutica* is an aggressive species, out-competing the native European caprellid *Caprella linearis* for space, even at low densities (Shucksmith in press). In the native range, this species is typically associated with either attached or drifting macroalgae, including *Sargassum* spp. or aquaculture structures, such as the ropes used for the culture of the macroalga *Undaria* spp. in Otsuchi Bay (Kawashima et al. 1999). In regions outside its native range, it has been found associated with areas of anthropogenic activity, such as harbours, marinas, navigation buoys and aquaculture sites (Willis et al. 2004, Ashton 2006, Kerckhof et al. 2007).

Carlton (1979) suggested that *C. mutica* arrived on the Pacific and Atlantic coasts of North America either as a result of numerous independent cross-oceanic introductions with oyster spat, or from small scale transport following its first introduction (Carlton 1996). Direct sequencing of mitochondrial DNA indicates that *C. mutica* was introduced to Europe either directly from Asia or from the Atlantic coast of North America (Ashton 2006). Opportunities for the spread of non-native species to Europe across the Atlantic have existed for more than 500 years with early exploration and the subsequent establishment of shipping routes (Stoner et al. 2002). For a little more than a century ships' ballast water has

Figure 1. Male (top) and female (bottom) *Caprella mutica* (Photo: T. Nickell)

transmitted many different crustacean taxa, including caprellids (Coutts et al. 2003) and in the last half-century ocean barges and oil platforms (or similar structures) have been moved across oceans (Rodríguez and Suaréz 2001, Ruiz and Hewitt 2002) and may have introduced *C. mutica* to Europe. The importation of different species of half-grown oysters as deck cargo since ~1870s (Loosanoff 1975) and of Pacific oysters (*Crassostrea gigas*) from British Columbia in the 1960s and later directly from Japan in the 1970s into Europe, may also have provided opportunities for introduction (Wolff 2005). *C. mutica* lacks a free-swimming planktonic larval stage and secondary movements are also likely to involve human activities, such as shipping, aquaculture activities and recreational boating or may otherwise be associated with drifting macroalgae (Ashton 2006).

C. mutica was first identified in European waters in 1994 in a harbour at Neeltje Jans in The Netherlands (M. Faasse, pers. obs.). In a review by Ashton et al. (2007a) its general occurrence in Europe is described. In this account, we report all known localities for this species in European waters and discuss the likely dispersal mechanisms involved in its further spread.

Methods and Materials

Published records and unpublished reports were consulted for verifiable material. Researchers with recorded sightings of *C. mutica* were contacted for further information and if possible, specimens were obtained for confirmation of identification using the taxonomic key by Arimoto (1976).

Results

One hundred and twenty-one records of *Caprella mutica* were found for European waters (Annex), including eleven new localities for 2007. Confirmed records for *C. mutica* are from the North Sea, English Channel, Irish Sea, the west coast of Scotland and Ireland (Figure 2) and range from 49°29'N to 62°22'N and 10°04'W to 8°26'E. While *C. mutica* was not found at all localities surveyed within this range, the region comprising the greatest number of records was the south-western North Sea. There are presently no records for the Baltic Sea, the Iberian Peninsula or the Mediterranean Sea.

The majority of the European records occur in areas with human activity, such as marinas, ports and shipping routes. In Norway and the west coast of Scotland, *C. mutica* is associated with aquaculture activity, principally fish cage netting and mussel lines. This species has also been found on natural substrata within the sub-littoral zone on the macroalga *Plocamium* spp. (K. Boos, pers. obs.) and attached to drifting surface accumulations of macroalgae (Ashton 2006).

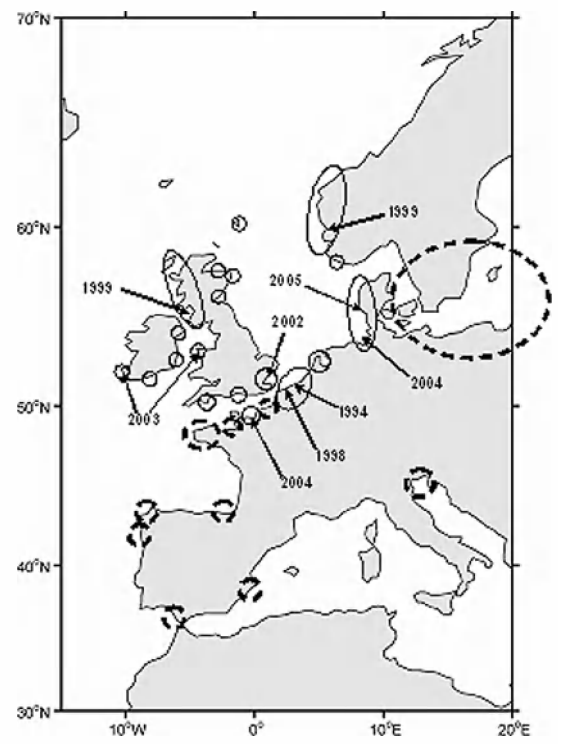

Figure 2. European distribution of *Caprella mutica*. Solid circles show confirmed sightings (including dates for first record in the country) and dotted circles show regions where *C. mutica* has not been recorded to date

Discussion

Dispersal of *Caprella mutica* within Europe has been rapid and represents ~1,200 km range extension to the west coast of Norway and ~1,000 km to the west coast of Ireland from where it was first recorded in The Netherlands. *C. mutica* has been found on boat hulls, fish cage netting, marina pontoons, navigation buoys, harbour structures and to attached floating macroalgae. Its abundance on artificial structures is notable and may explain its ability to spread rapidly. *C. mutica* lacks a planktonic stage, the young hatch onto the substrate in the form of small adults, and their long-range distribution most probably depends on the movement of floating artificial structures, such as vessels, whilst attachment to floating marine algae may account for more localised movements.

A genetic study indicates two likely routes for the introduction of this species to Europe, including cross-oceanic introductions either directly from Asia or via the Atlantic coasts of the United States (Ashton 2006). Shipping has been identified as an important pathway for the transoceanic introduction of non-native species (Drake and Lodge 2004). Many of the areas in Europe where *C. mutica* has been introduced are close to busy ports suggesting that ballast water transport and/ or hull fouling could be involved. Living *Caprella* spp. have been found in ships' ballast tanks (Carlton 1985) and in sea-chests in a study in New Zealand (Coutts et al. 2003). Within its native environment, *C. mutica* may be found attached to the macroalgae *Ulva* spp. and the filamentous *Cladophora* spp. and these are regularly found attached to ships hulls (Mineur et al. 2007). It has also been seen associated with other algae at high densities on recreational boat hulls (Minchin and Holmes 2006, G Ashton, pers. obs. and R Shucksmith, pers. comm.) and in the Adriatic Sea *Caprella scaura* is thought to have been spread on the hulls of leisure craft (Sconfietti et al. 2005).

Stock movements of cultured species have also been identified as one means of globally spreading non-native species (Ruiz and Hewitt 2002, Minchin 2007a). Introduction of *C. mutica* to the United States has been potentially linked to the importation of the Pacific Oyster, *C. gigas* for culture purposes (Carlton 1987). Elsewhere there are several examples of species being inadvertently spread with oysters that include

algae (Scagel 1956, Druehl 1973, Critchley 1983), molluscs (Cole 1942), bryozoa (De Blauwe and Faasse 2004) and crustaceans (Gruet et al. 1976). The Oosterschelde region in The Netherlands has received extensive shellfish imports and these movements may have been responsible for the introduction of *C. mutica* to Europe (Wolff 2005). However, this region was regularly sampled between 1990-1995 and *C. mutica* was not found (M. Faasse, pers. obs.). This suggests that the introduction to Europe of *C. mutica* is more likely to be via commercial shipping rather than stock movements of cultured species.

Dispersal of *C. mutica* within Europe has been rapid. It is likely, therefore, that commercial and recreational vessels will continue to spread this species to unoccupied areas within its present range, as well as, to localities beyond where it presently occurs particularly in the summer months, when there is the greatest leisure vessel activity and highest densities of *C. mutica*. On the west coast of Scotland, their abundance can reach 300,000 individuals m^{-2} and fish farm cages (Ashton 2006) and other structures can be dominated by this species between July and August (Cook et al. 2006) (Figure 3). It is possible though, that the rapid range expansion to fish farm installations in Scotland (Willis et al. 2004), Ireland (Tierney et al. 2004) and in Norway (A. Jelmert, pers. comm.) and navigation buoys in Belgium and The Netherlands (F. Kerchkof, pers. obs.) may be with movements of service craft. In California, USA, the appearance of *C. mutica* on oil platforms offshore is thought to be due to transmissions with service craft from harbours (C. Culver, pers. comm.). Such expansion to offshore facilities may create a 'stepping-stone' effect, thereby enhancing opportunities for further range extensions. Spread could also be aided by attachment to drift algae but it is unclear how far *C. mutica* could be dispersed in this way, although algal rafts are known to persist for long durations (Ingolfsson 1995).

The present records of *C. mutica* all occur within the current global range of this species. Its tolerance to a wide range of temperatures and capability of surviving in marine to brackish water (Ashton et al. 2007b) would indicate that it is likely to expand its range further within Europe. It is unlikely to survive in the central and eastern Baltic Sea due to low salinities (FIMR 2006), and based on current knowledge it is not expected to become established in the Mediterranean Sea on account of the high summer seawater temperatures (Cook et al. 2006).

Figure 3. Experimental frame deployed west of Zeebrugge, Belgium in 2007 showing dense aggregations of *Caprella mutica* after 12 weeks immersion (Photo: F. Kerckhof)

The abundance of *C. mutica* on artificial substrata would indicate that conditions on such structures are in some way particularly suited for their survival and development, such as the lack of benthic predators. Should hull fouling be important in its range expansion it may be expected that their northward expansion in Norway will be slow, when compared with the north and west coasts of France and the Iberian Peninsula where there is a higher level of leisure craft and shipping activity. Other additional factors, that might limit their range expansion and/ or establishment in natural habitats include substrate features (Caine 1978), wave exposure (Takeuchi et al. 1987, Guerra-García 2001), high levels of predation (Guerra-García and García-Gómez 2001) or port toxicity (Ohji et al. 2003).

Conclusions

Caprella mutica has become established in the North Sea, west coasts of Scotland and Ireland, in the Irish Sea and English Channel in less than 14 years. Since this species has a tolerance for a wide range of temperature and salinity, it is likely that it will expand its current range further

north in Norway, to several Atlantic islands, the Bay of Biscay and the Iberian Peninsula; but it may not become established in the Mediterranean Sea or in the eastern Baltic Sea, where salinities fall below 19 ppt. *C. mutica* is thought to expand its range rapidly either by attachment to vessels or with drifting algae. It out-competes native caprellids under laboratory conditions and it is likely to behave in the same way in the field where it attains high densities. Whilst the wider environmental implications of *C. mutica* have not yet been confirmed, it is likely that it has an important impact on benthic communities.

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Annex

European distribution records of *Caprella mutica* including location, latitude and longitude, date of reporting and site description (if known). Confirmed non-sightings are also included.

Location/Country	Geographic coordinates		Date	Site description	Source
	Latitude	Longitude			
Neeltje Jans Binnenhaven, Netherlands	51°37' N	03°41' E	Summer, 1994	Harbour	M. Faasse (pers. obs.)
Burghsluis, Netherlands	51°40' N	03°45' E	1995	Pontoon & scaffolding	Platvoet et al. 1995
Neeltje Jans Buitenhaven, Netherlands	51°37' N	03°41' E	April, 1996	Harbour	M. Faasse (pers. obs.)
Goesse Sas, Netherlands	51°33' N	03°56' E	June, 1996	Seadyke	M. Faasse (pers. obs.)
Katse Hoek, Netherlands	51°34' N	03°54' E	June, 1996	Seadyke	M. Faasse (pers. obs.)
's Gravenhoek, Netherlands	51°39' N	03°48' E	July, 1996	Seadyke	M. Faasse (pers. obs.)
Kattendijke, Netherlands	51°32' N	03°58' E	July, 1996	Seadyke	M. Faasse (pers. obs.)
Borssele, Netherlands	51°25' N	03°43' E	August, 1997	Power station	M. Faasse (pers. obs.)
Zierikzee west, Netherlands	51°38' N	03°53' E	September, 1997	Seadyke	M. Faasse (pers. obs.)
Off Zeebrugge east, Belgium	51°37' N	3°41' E	January, 1998	Open water buoy (S12)	F. Kerckhof (pers. obs.)
Off Zeebrugge west, Belgium	51°2'N	3°00' E	March, 1998	Open water buoy (SWW)	F. Kerckhof (pers. obs.)
Off Zeebrugge west, Belgium	51°23'N	2°58' E	November, 1998	Open water buoy (S2)	F. Kerckhof (pers. obs.)
Off Zeebrugge east, entrance river Scheldt, Belgium	51°23'N	3° 18' E	July, November, 1998	Open water buoys (W1 and SW)	F. Kerckhof (pers. obs.)
Port of Zeebrugge, Belgium	51°19' N	3°12' E	July, March, November, 1998	Marina and buoys (Z10, Z8, ZoK N)	F. Kerckhof (pers. obs.) H. De Blauwe (pers. comm.)
Neeltje Jans buoy, Netherlands	51°37' N	03°42' E	April, 1998	Open water buoy	M. Faasse (pers. obs.)
Neeltje Jans Vluchthaven, Netherlands	51°38' N	03°42' E	May, 1998	Aquaculture	M. Faasse (pers. obs.)
Zeebrugge, Belgium	51°19' N	03°12' E	1999	Marina	H. De Blauwe (pers. comm.)
Off Zeebrugge in front of harbour entrance, Belgium	51°22' N	03°10' E	May, 1999	Open water buoy (WZ)	F. Kerckhof (pers. obs.)
Off Zeebrugge, northwest , Belgium	51°24' N	03°03' E	July, 1999	Open water buoy (S3)	F. Kerckhof (pers. obs.)
Hordaland, Norway	60°14' N	06°00' E	1999	Harbour	Heilscher 2000
Clyde Sea, Scotland, UK	55°57' N	04°52' W	August, 1999	Navigation buoy	O'Reilly 2007
Port of Zeebrugge, Belgium	51°19' N	03°12' E	January, October, 2000	Port (ZA1, ZA4)	F. Kerckhof (pers. obs.)
Goesse Meer, Netherlands	51°31' N	03°55' E	July, 2000	Inland water	M. Faasse (pers. obs.)
Breskens, Netherlands	51°24' N	03°34' E	October, 2000	Marina	M. Faasse (pers. obs.)
Bruinisse, Netherlands	51°40' N	04°06' E	November, 2000	Harbour	M. Faasse (pers. obs.)
List, Sylt, Germany	55° 00' N	08°26' E	2000	Unknown	Buschbaum and Gutow 2005
Helgoland, Germany	54°10' N	07°53' E	2000	Unknown	Buschbaum and Gutow 2005
Oban, Scotland, UK	56°26' N	05°26' W	July, 2000	Fish farm	Willis et al. 2004

Annex (continued)

Location/Country	Geographic coordinates		Date	Site description	Source
	Latitude	Longitude			
Wissenkerke east, Netherlands	51°36' N	03°47' E	August, 2001	Seadyke	M. Faasse (pers. obs.)
Goesse Sas Marina, Netherlands	51°32' N	03°56' E	November, 2001	Marina	M. Faasse (pers. obs.)
Wissenkerke, Netherlands	51°36' N	03°45' E	June, 2001	Seadyke	M. Faasse (pers. obs.)
Zoetersbout, Netherlands	51°39' N	04°06' E	June, 2001	Seadyke	M. Faasse (pers. obs.)
Oostende, Belgium	51°13' N	02°54' E	April, 2002	Small buoy in front of harbour	F. Kerckhof (pers. obs.)
Off Zeebrugge east, Belgium	51°24' N	03°18' E	April, 2002	Open water buoy (S12)	F. Kerckhof (pers. obs.)
Harwich, England, UK	51°56' N	01°16' E	June, 2002	Harbour	Ashelby 2005
Vlissingen, Netherlands	51°26' N	03°35' E	July, 2002	Marina	M. Faasse (pers. obs.)
Zierikzee, Netherlands	51°38' N	03°55' E	July, 2002	Seadyke	M. Faasse (pers. obs.)
Wemeldinge, Netherlands	51°31' N	04°00' E	August, 2002	Marina	M. Faasse (pers. obs.)
Alesund, Norway	62°29' N	06°23' E	2002		WGITMO 2003, A. Jelmert (pers. comm.)
Off Zeebrugge in front of harbour entrance, Belgium	51°22' N	03°10' E	August, 2003	Open water buoy (WZ)	F. Kerckhof (pers. obs.)
Blankenberge, Belgium	51°19' N	03°07' E	October, 2003	Small temporary buoys in front of harbour	F. Kerckhof (pers. obs.)
Port of Zeebrugge, Belgium	51°19' N	03°12' E	July, November, 2003	Port (buoys ZoK N, ZW1)	F. Kerckhof (pers. obs.)
Southampton, England, UK	50°53' N	01°23' W	2003	Harbour	L. Baldock & M. Marley (pers. comm.)
Bertraghboy Bay, Ireland	53°29' N	10°04' W	2003	Fish farm	Tierney et al. 2004
Hidra, Norway	58°15' N	06°32' E	2003	Aquaculture	A. Jelmert (pers. comm.)
Austevoll, Norway	60° 06' N	05°15' E	2003	Aquaculture	A. Jelmert (pers. comm.)
Shetland Is, Scotland, UK	60°22' N	01°12' W	2003	Mussel lines	G. Duncan (pers. comm.)
Anglesey, Wales, UK	53°18' N	04°37' W	August, 2003	Mooring line	T. Stoker (pers. comm.)
Off Zeebrugge, west , Belgium	51°02' N	03°02' E	September, 2004	Open water buoy (WBN)	F. Kerckhof (pers. obs.)
Southampton, England, UK	50°53' N	01°23' W	2004	Pontoons	Arenas et al. 2006
Poole Quay, England, UK	50°42' N	01°59' W	2004	Pontoons	Arenas et al. 2006
Le Havre, France	49°29' N,	00°07' E	2004	Harbour	G. Breton (pers. comm.)
List, Sylt, Germany	55° 00' N	08°26' E	October, 2004	Pontoons	Buschbaum and Gutow 2005
Helgoland, Germany	54°10' N	07°53' E	October, 2004	Pontoons	Buschbaum and Gutow 2005
Dunstaffnage Bay, Scotland, UK	56°27' N	05°26' W	April, 2004	Marina	Ashton 2006
Lamlash, Scotland, UK	55°31' N	05°07' W	May, 2004	Fish Farm	Ashton 2006
Clyde Basin, Scotland, UK	55°57' N	04°52' W	May, 2004	Fish Farm	Ashton 2006
Loch Fyne, Scotland, UK	55°56' N	05°23' W	May, 2004	Fish Farm	Ashton 2006
Fishnish, Scotland, UK	56°30' N	05°48' W	May, 2004	Fish Farm	Ashton 2006

Annex (continued)

Location/Country	Geographic coordinates		Date	Site description	Source
	Latitude	Longitude			
Lismore, Scotland, UK	56°30' N	05°30' W	May, 2004	Fish Farm	Ashton 2006
Shuna, Scotland, UK	56°12' N	05°36' W	May, 2004	Fish Farm	Ashton 2006
Kinlochleven, Scotland, UK	56°42' N	04°58' W	May, 2004	Fish Farm	Ashton 2006
Loch Sunart, Scotland, UK	56°41' N	05°46' W	May, 2004	Fish Farm	Ashton 2006
Lochboisdale, Scotland, UK	57°09' N	07°18' W	May, 2004	Fish Farm	Ashton 2006
Loch Carnan, Scotland, UK	57°22' N	07°16' W	May, 2004	Fish Farm	Ashton 2006
Loch Kishorn, Scotland, UK	57°21' N	05°40' W	May, 2004	Fish Farm	Ashton 2006
Loch Torridon, Scotland, UK	57°34' N	05°46' W	May, 2004	Fish Farm	Ashton 2006
Loch Maddy, Scotland, UK	57°36' N	07°09' W	May, 2004	Fish Farm	Ashton 2006
Cheese Bay, Scotland, UK	57°39' N	07°06' W	May, 2004	Fish Farm	Ashton 2006
Loch Ewe, Scotland, UK	57°48' N	05°37' W	May, 2004	Fish Farm	Ashton 2006
Loch Tarbert, Scotland, UK	55°51' N	05°26' W	May, 2004	Fish Farm	Ashton 2006
Loch Seaforth, Scotland, UK	57°57' N	06°43' W	May, 2004	Fish Farm	Ashton 2006
Loch Shell, Scotland, UK	58°00' N	06°30' W	May, 2004	Fish Farm	Ashton 2006
Loch Erisort, Scotland, UK	58°05' N	06°29' W	May, 2004	Fish Farm	Ashton 2006
Loch Roag, Scotland, UK	57°26' N	06°35' W	May, 2004	Fish Farm	Ashton 2006
Calbha Bay, Scotland, UK	58°17' N	05°07' W	May, 2004	Fish Farm	Ashton 2006
Loch Laxford, Scotland, UK	58°22' N	05°01' W	May, 2004	Fish Farm	Ashton 2006
Off Zeebrugge west , Belgium	51°23' N	02°46' E	June, 2005	Open water buoy (VG)	F. Kerckhof (pers. obs.)
Off Zeebrugge, northwest, Belgium	51°24' N	03°03' E	September, 2005	Open water buoy (S3)	F. Kerckhof (pers. obs.)
Off Zeebrugge west, Belgium	51°22' N	03°05' E	September, 2005	Open water buoy (Nippon)	F. Kerckhof (pers. obs.)
Off Oostende harbour, Belgium	51°14' N	02°53' E	October, 2005	Open water buoy (Buitenstroombank	F. Kerckhof (pers. obs.)
Horns Rev Windfarm, Denmark	55°27' N	08°26' E	2005	Windfarm	R. Frederiksen (pers. comm.)
Wangerooge, Germany	53°47' N	07°54' E	July, 2005	Pontoons	Schrey 2006
Hoernum, Sylt, Germany	54°45' N	08°17' E	October, 2005	Pontoons	Schrey 2006
Dun Laoghaire, Dublin Bay, Ireland	54°03' N	06°11'W	2005	Marina pontoons & floating algae	Minchin and Holmes 2006
Anna Jacobapolder, Netherlands	51°39' N	04°06' E	July, 2005	Harbour	M. Faasse (pers. obs.)
Wolphaartsdijk, Netherlands	51°33' N	03°49' E	July, 2005	Seadyke	M. Faasse (pers. obs.)
Texel, Netherlands	53°02' N	04°41' E	March, 2005	Buoy (MG 10)	F. Kerckhof (pers. obs.)
Texel, Netherlands	53°02' N	04°41' E	October, 2005	Buoy (MG 1A)	F. Kerckhof (pers. obs.)

Annex (continued)

Location/Country	Geographic coordinates		Date	Site description	Source
	Latitude	Longitude			
Marsdiep, Netherlands	53°04' N	05°28' E	2005	Mussel Lines	W. Lewis (pers. comm.)
Malzwin, Netherlands	53°03' N	05°27' E	2005	Mussel Lines	W. Lewis (pers. comm.)
Loch Linnhe, Scotland, UK	56°31' N	05°26' W	May, 2005	Floating macroalgae	Ashton 2006
Loch Beag, Scotland, UK	56°53' N	05°44' W	June, 2005	Mussel Lines	E. Cook (pers. obs.)
Loch Creran, Scotland, UK	56°31' N	05°20' W	August, 2005	Boat hull	R. Shucksmith (pers. comm.)
Oban, Scotland, UK	56°25' N	05°30' W	August, 2005	Mooring lines, pontoons, kelp beds	R. Shucksmith (pers. comm.)
Off Zeebrugge, east, Belgium	51°24' N	03°18' E	March, 2006	Open water buoys (S12 and S10)	F. Kerckhof (pers. obs.)
Off Zeebrugge, northwest, Belgium	51°23' N	03°05' E	July, 2006	Open water buoy (S5)	F. Kerckhof (pers. obs.)
Port of Zeebrugge, Belgium	51°19' N	03°12' E	October, 2006	Port buoy (ZA2)	F. Kerckhof (pers. obs.)
Off Nieuwpoort, Belgium	51°13' N	02°38' E	November, 2006	Open water buoy from mussel cultivation project	F. Kerckhof (pers. obs.)
Off Zeebrugge, east, Shipping route, Belgium	51°24' N	02°44' E	November, 2006	Open water buoy (GZ)	F. Kerckhof (pers. obs.)
Off Zeebrugge, west, Belgium	51°22' N	03°07' E	December, 2006	Open water buoy (A2)	F. Kerckhof (pers. obs.)
Cork Harbour, Ireland	51°50' N	08°16' W	July, August, 2006	Marina pontoons	Minchin 2007b
Carlingford Lough, Ireland	54°03' N	06°11' W	July, August, 2006	Marina pontoons	Minchin 2007b
Ardrossan, Scotland, UK	55°38' N	04°49' W	August, 2006	Marina pontoons	Ashton et al. 2006
Troon, Scotland, UK	55°33' N	04°42' W	August, 2006	Marina pontoons	Ashton et al. 2006
Peterhead, Scotland, UK	57°29' N	01°47' W	August, 2006	Marina pontoons	Ashton et al. 2006
Port Edgar, Scotland, UK	55°60' N	03°25' W	August, 2006	Marina pontoons	Ashton et al. 2006
Lossiemouth, Scotland, UK	57°43' N	03°16' W	August, 2006	Marina pontoons	Ashton et al. 2006
Ardfern, Scotland, UK	56°11' N	05°32' W	August, 2006	Marina pontoons	Ashton et al. 2006
Croabh Haven, Scotland, UK	56°13' N	05°33' W	August, 2006	Marina pontoons	Ashton et al. 2006
Off Zeebrugge west , Belgium	51°32' N	02°22' E	March, 2007	Open water buoy (VG2)	F. Kerckhof (pers. obs.)
Off Zeebrugge, Belgium	51°27' N	02°09' E	July, 2007	Open water buoy (NE Akkaert)	F. Kerckhof (pers. obs.)

Annex (continued)

Location/Country	Geographic coordinates		Date	Site description	Source
	Latitude	Longitude			
Koksijde, Belgium	51°07' N	02°36' E	October, 2007	Small temporary buoy	F. Kerckhof (pers. obs.)
Zeebrugge West, Belgium	51°22' N	03°07' E	October, 2007	Experimental Frame	F. Kerckhof (pers. obs.)
Plymouth, England, UK	50°22' N	04°08' W	July, 2007	Marina pontoons	J. Bishop (pers. comm.)
Helgoland, Germany	54°10' N	07°53' E	October, 2007	Macroalga, Plocamium spp.	K. Boos (pers. obs.)
Sture, Norway	60°49' N	03°30' E	2007	Abandoned fish farm	H. Botnen (pers. obs.)
Nyhamna, Norway	62°50' N	06°54' E	2007	New harbour for gas processing plant	H. Botnen (pers. obs.)
Loch Fyne, Scotland, UK	56°09' N	05°11' W	May, 2007	Fishing boat hull	P. Smith (pers. comm.)
Loch Melfort, Scotland, UK	56°15' N	05°32' W	July, 2007	Boat hull	E. Cook (pers. obs.)
Largs, Scotland, UK	55°46' N	04°51' W	August, 2007	Marina pontoons	E. Cook (pers. obs.)
Regions where *C. mutica* has not been found to date					
HELCOM Baltic, Finland					E. Leppäkoski (pers. comm.)
Dunkerque, Calais, Boulogne and Boullonais coast, France				Ports	Belgium Strandwerkgroep (pers. comm.)
Granville, Normandy, France				Port	Belgium Strandwerkgroep (pers. comm.)
Brittany, France				Coastal survey	Belgium Strandwerkgroep (pers. comm.)
Venice Lagoon, Italy	45°27' N	12°19' E			A. Occhipinti (pers. comm.)
Cadiz, Spain	36°31' N	6°17' W			J. M. Guerra García (pers. comm.)
Alicante, Spain	38°25' N	0°22' W			J. M. Guerra García (pers. comm.)
Adriatic Sea, Slovenia/ Croatia					A. Malej (pers. comm.)
Basque coast, Spain					Belgium Strandwerkgroep (pers. comm.)
La Coruna and adjacent region, Spain	43°22' N	8°23' W			F. Kerckhof (pers. obs.)
Ria de Vigo and adjacent region, Spain	42°13' N	8°46' W			F. Kerckhof (pers. obs.)