

Asian Shore Crabs *Hemigrapsus* spp. (Crustacea: Brachyura: Grapsoidea) continue their invasion around the Cotentin Peninsula, Normandy, France: Status of the *Hemigrapsus* population in 2009

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Abstract

This paper reports on the state of the Asian shore crab *Hemigrapsus sanguineus* (de Haan, 1835) population around the Cotentin Peninsula (Normandy, France) for 2009. As in 2008, the year of the first survey, the northern and eastern Cotentin coasts remain the most densely colonised. On the western shore, *H. sanguineus* remains rare, except in two sites not surveyed in 2008. In the east most colonised sites, Gatteville-Phare and La Hougue, the populations for both years indicate a rapid increase of abundance: maximum density > 50 ind.m⁻² in 2009 compared to 10 ind.m⁻² in 2008. This observation probably demonstrates that the species' current significant increase is comparable to that of an invasive species. A second species of Asian shore crab *Hemigrapsus takanoi* Asakura & Watanabe, 2005 was only present on one eastern site off Saint-Vaast-La-Hougue, but remains isolated.

Key words: marine invasive species, *Hemigrapsus sanguineus*, *Hemigrapsus takanoi*, English Channel, Cotentin coast

Introduction

Two species of Asian crabs of the genus *Hemigrapsus* have colonised the French Atlantic and Channel coasts (Noël et al. 1997; Breton et al. 2002; Noël and Gruet 2008; Dauvin 2009a; Dauvin et al. 2009). The first was the brush-clawed shore crab *H. takanoi* Asakura & Watanabe 2005 initially identified as *H. penicillatus* (de Haan 1835) and was reported for the first time in La Rochelle on the Atlantic coast of France in 1994 (Noël et al. 1997); it is today present in the Bay of Biscay, from the Spain coast to the Morbihan Gulf (Noël et al. 1997; Breton et al. 2002; Noël and Gruet 2008) and from the eastern part of the Cotentin in the Eastern English Channel to the tidal zone near Norddeich along the German coast (Dauvin et al. 2009). The second species *H. sanguineus* (de Haan 1835) was discovered in Le Havre harbour in 1999 (Breton et al. 2002) and has been recorded along the European coast from the western coast of the Cotentin in the English Channel to the state of Schleswig-Holstein along

the German coast (Dauvin et al. 2009). In the Channel, both species formed abundant populations in 2008 along the Opal Coast (French side of the Dover Strait): *H. sanguineus* occurred in large numbers on the rocky shore of the open sea, while *H. takanoi* was abundant in sheltered harbours (Dauvin et al. 2009). Moreover, *H. sanguineus* formed abundant populations in 2008 in the eastern part of the Cotentin, a peninsula that divides the English Channel (north-eastern Atlantic) into two basins, west and east (Dauvin 2009a).

The aim of this short communication is to report the new sightings of both Asian species in Cotentin in July-August 2009 and to compare their status in 2009 with that of 2008.

Material and Methods

Field site

A total of nineteen sites were sampled from 13 July to 20 August 2009, including two harbours, Granville and Carteret; three protected sites,

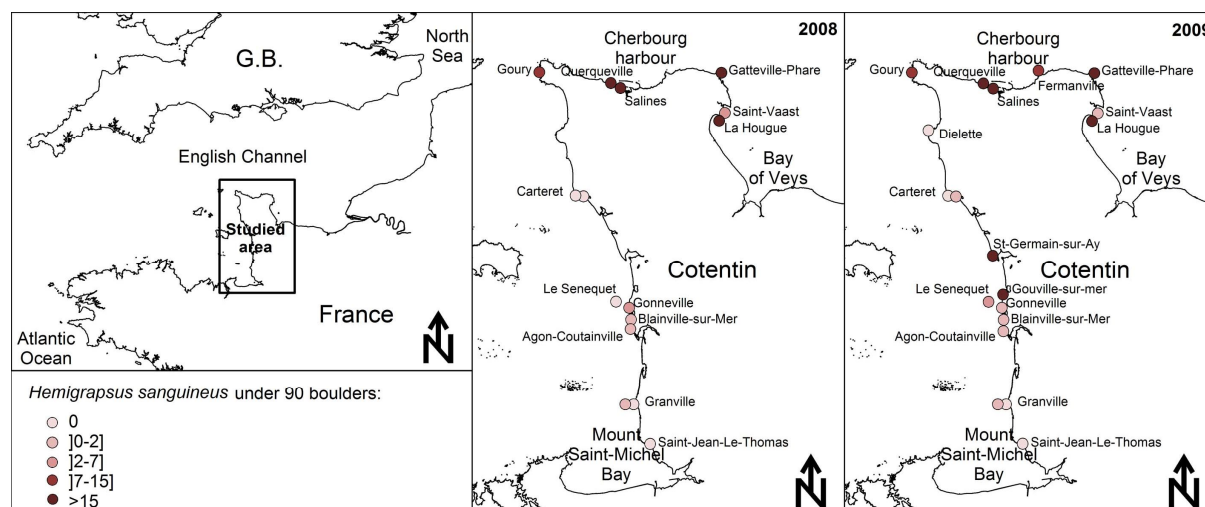


Figure 1. Five colonisation categories, based on the number of individuals sampled under 90 boulders, were established for *Hemigrapsus sanguineus* at the 15 sites sampled during the summer of 2008 and the 19 sites sampled during the summer of 2009 around the Cotentin Peninsula

Querqueville, Salines and Saint-Vaast; and 14 other sites located in areas with relatively high hydrodynamics around the Cotentin Peninsula (Figure 1, Table 1, and Annex 1). Four new sites were surveyed in 2009: Gouville-sur-mer, Saint Germain-sur-Ay and Dielette on the western coast of Cotentin and Fermanville on the northern coast of Cotentin (Figure 1).

Sampling procedure

At each of the 19 sampling sites (Figure 1, Annex 1), *Hemigrapsus* were counted under three groups of the 30 boulders sampled in the mid-littoral zone, for a total of 90 boulders per site. This sampling design was adopted for estimating the abundances of the shore crabs (Dauvin 2009a; Dauvin et al. 2009). Three sites - Querqueville, Gatteville-Phare and La Hougue - corresponded to highly colonised zones; estimations of the density of *H. sanguineus* were made based on a quadrat of 1 m², with three replicates being done at each of the three sites (Table 1).

Laboratory observations

Hemigrapsus crabs were collected, identified, counted, measured (carapace width taken across the first pair of anterior lateral teeth) and sexed. The class-size histograms were constructed with 2 mm classes.

Results

Table 1 and Annex 1 provide all the results for the 2009 survey. The major points of the 2009 survey were: 1). Of the four new sites surveyed, only one - Dielette - in a very highly hydrodynamic zone with round granite boulders presented no Asian crabs. *H. sanguineus* were present in the three other sites, though with only eight individuals under the 90 boulders at Fermanville on the northern coast of Cotentin and 27 and 24 individuals respectively at Gouville-sur-mer and Saint Germain-sur-Ay on the western coast of the Cotentin; 2). Two new sites were colonised in 2009 on the western coast of Cotentin - Le Senéquet and Carteret harbours; 3). The highly hydrodynamic zones, such as those found along the western coast of the Cotentin (i.e., Carteret and Dielette) were not colonized; 4). The northern coast of Cotentin remained the most colonized (Figure 1, Table 1); 5). The level of colonisation at the 15 sites sampled both in 2008 and 2009 remained in the same range of magnitude, except for two sites on the eastern Cotentin coast - Gatteville-Phare and La Hougue—where the abundance increased dramatically between 2008 and 2009 (Table 2).

The size of *Hemigrapsus sanguineus* individuals sampled in 2009 ranged from 4.8 mm for the smallest to 35.6 mm for the largest (Table 3). At Querqueville, Gatteville-Phare and La Hougue, the size-class frequencies showed similar

patterns of individual distribution, with three modes (Figure 2). But the position of the modal classes changed from one site to the other. The first modal class - young individuals < 10 mm at

8-10 mm, which were probably crabs in their first year - was similar in the three sites. The second modal class was respectively 14-16 mm at Gatteville-Phare, 16-18 mm at La Hougue and

Table 1. Main characteristics of the *Hemigrapsus sanguineus* collected in the sites and on the sampling dates during the summer of 2009 (N: number; T: total; G1, G2, and G3: groups of 30 boulders; S.D.: Standard Deviation of the mean; % of ovigerous females= number of ovigerous female/total number of females)

Sites	Date	N G1	N G2	N G3	T	Mean N± S.D.	Males N (M)	Females N (F)	Sex-ratio M/F	% of ovigerous females
Saint-Jean-Le-Thomas	14/07	0	0	0	0	0	-	-	-	-
Granville harbour	14/07	0	0	0	0	0	-	-	-	-
Granville outer harbour	14/07	0	0	1	1	0.33±0.58	1	0	-	-
Agon-Coutainville	14/07	1	0	1	2	0.66±0.58	1	1	1	-
Blainville sur mer	15/07	2	0	0	2	0.66±1.15	2	0	0	-
Gonneville	13/07	1	0	1	2	0.66±0.58	1	1	1	100
Le Senéquet	20/08	0	0	3	3	1±1.73	2	1	2.00	0
Gouville sur mer	17/07	8	3	16	27	9±6.57	9	18	0.33	66.67
Saint Germain sur Ay	17/07	14	4	6	24	8±5.29	13	11	1.18	72.72
Carteret harbour	16/07	0	0	1	1	0.33±0.58	1	-	-	-
Carteret outer harbour	16/07	0	0	0	0	0	-	-	-	-
Dielette	10/08	0	0	0	0	0	-	-	-	-
Goury	10/08	3	4	6	13	4.33±1.52	7	6	1.17	50.00
Querqueville	10/08	25	24	33	82	27.33±4.93	38	44	0.86	77.27
Salines	10/08	4	7	6	17	5.66±1.53	5	12	0.39	69.23
Fermanville harbour	11/08	1	2	5	8	2.67±2.08	6	2	3.0	0.00
Gatteville-Phare	11/08	62	46	44	152	50.67±9.87	68	84	0.81	70.23
Saint-Vaast	11/08	1	0	1	2	0.66±0.58	2	0	-	-
La Hougue	11/08	70	69	63	202	67.33±3.79	70	132	0.53	78.78
							-	-	-	-
Querqueville (m ²)	10/08	12	18	19	49	16.33±3.79	20	29	0.69	79.31
Gatteville-Phare (m ²)	11/08	33	34	31	98	32.67±1.53	45	53	0.85	49.06
La Hougue (m ²)	11/08	51	53	56	160	53.33±2.51	48	112	0.43	77.68
Total					845		339	506	0.67	

Table 2. Number and density (N. ind. m⁻²) of *Hemigrapsus sanguineus* in 2008 and 2009 at the three most colonised sites in the Cotentin

Sites	N. individuals under 90 boulders		N. individuals per m ²	
	2008	2009	2008	2009
Querqueville	93	82	9.7	16.3
Gatteville-Phare	83	152	-	32.6
La Hougue	77	202	-	53.3

18-20 mm at Querqueville. The third modal class was respectively 18-20 mm at Gatteville-Phare, 20-22 mm at La Hougue and 22-24 mm at Querqueville. In this last site, the ovigerous females also clearly displayed two modal classes, the first at 16-18 mm (one year old) and the second at 22-24 mm (two years old). In the other two sites, the ovigerous females showed a single modal class, being 18-20 mm at Gatteville-Phare and 20-22 mm at La Hougue. At all three sites, the largest individuals (i.e., > 26 mm) represented probably the individuals over three years of age. These individuals represented a high proportion of the population only at La Hougue, where the largest female and male were collected.

Figure 3 shows the size-class frequency of the 845 individuals collected during the summer of 2009 around the Cotentin Peninsula. Only two modal classes were present: young individuals measuring 6-10 mm and the rest of the population measuring from 10 to 35.6 mm, including all individuals over one year of age. Comparing the sizes of the males and females surveyed in 2008 and 2009 (Table 3) revealed that the ovigerous females were smaller in 2009. Males were the largest crab found in 2009 as in 2008.

Table 3. Comparison of the size of the smallest and largest *Hemigrapsus sanguineus* male and female sampled around the Cotentin Peninsula in 2008 and 2009

Size in mm	2008	2009
Smallest male	5.0	4.8
Smallest female	6.0	6.1
Smallest ovigerous female	13.0	11.1
Largest female	31.0	28.6
Largest ovigerous female	31.0	28.6
Largest male	34.0	35.6

As shown in Table 1, the male/female sex-ratio for all the 845 specimens collected was 0.67, indicating that the number of females was higher than males. This ratio was lower than the one observed in 2008 (0.81), suggesting a more successful female colonisation. However, the sex-ratio was different in the three most colonised sites: 0.82 at Gatteville-Phare, 0.79 at Querqueville and only 0.48 at La Hougue. In the most colonised site at La Hougue, the proportion of the ovigerous females was also the highest (see Table 1 and Figure 2).

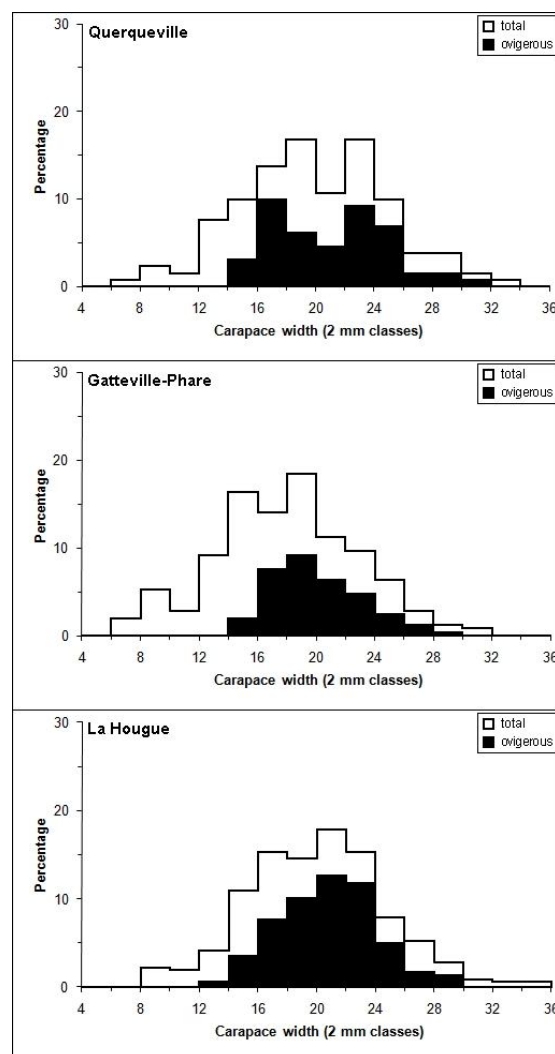


Figure 2. Frequency distribution of carapace-width classes of *Hemigrapsus sanguineus* collected at Querqueville (131 individuals), Gatteville-Phare (250 individuals) and La Hougue (362 individuals) from August 2009

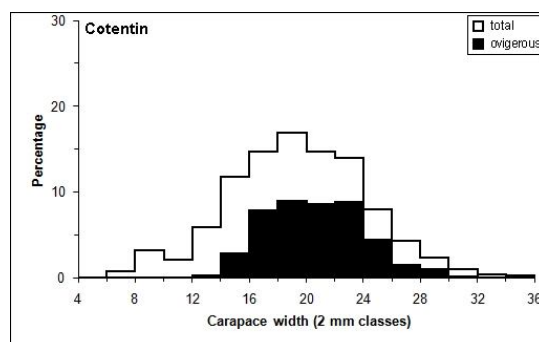


Figure 3. Frequency distribution of carapace-width classes of the 845 *Hemigrapsus sanguineus* collected at 15 sites sampled during the summer 2009

Discussion

Considering results of previous studies (Dauvin 2009a), I recommended a regular, perhaps annual, survey of the colonisation of *Hemigrapsus* crabs around the Cotentin Peninsula to evaluate their densities and range expansion. Clearly, the 2009 sampling confirmed the presence and expansion of the *Hemigrapsus sanguineus* population around the Cotentin. These 2009 observations demonstrated that there was a general increase of the intertidal *Hemigrapsus sanguineus* crab population: two new colonised sites on the western coast when no *H. sanguineus* had been collected in 2008, the discovery of two new colonised sites with abundant populations on the western coast (i.e., Gouville-sur-mer and Saint Germain-sur-Ay, and a great increase of the population at the eastern sites in Gatteville-Phare and La Hougue (Table 2).

The *Hemigrapsus sanguineus* densities observed in 2009 at La Hougue (Tables 1, 2 and 4) are today the maximum densities measured in the European waters. Nevertheless, this density remains lower than those estimated along the north-eastern American coast (Table 4). In 2001-2002, the maximum density of this Asian crab was observed at a site in western Long Island Sound, where the density values reached 350 ind.m⁻² (Kraemer et al. 2007). This is seven times more than the one observed at the Hougue.

As suggested by Dauvin (2009a), the original location of the Cotentin *Hemigrapsus sanguineus* population was probably Le Havre Harbour. The

primary introduction at the end of the 1990' (first observation in the Le Havre Harbour in 1999) was probably due to larval introduction in water ballast in this international harbour (Breton et al. 2002). Then, the species extended its population through the residual coastal circulation in the Bay of Seine which insure larval dispersion (Le Hir et al. 1986). The fact that it was on the north-eastern coast of the Cotentin where the population increase was the highest reinforces this physical and biological coupling. As a result of a permanent gyre in this north-western part of the Bay of Seine, crab larvae were probably retained in this area, as has been observed in other marine invertebrate species (e.g., *Ophiothrix fragilis* Abildgaard, 1789) (Lefebvre et al. 2003). This retention phenomenon could contribute to the large population increase in this zone. To confirm this hypothesis, it would be necessary to catch the larvae with zooplankton nets.

Three areas with favourable habitats for the second invasive species *H. takanoi* - Carteret Harbour, Granville Harbour and Saint-Jean-le-Thomas - are not yet colonised by this species; however, these three sites are located on the western coast of the Cotentin which are not nowadays colonised by this species. Like in 2008, *H. takanoi* was found in 2009 at a single site off Saint-Vaast. Three individuals were found: one juvenile male (size: 9.6 mm) and two ovigerous females (size: 16.0 and 19.8 mm, respectively). Along the eastern coast of the Cotentin Peninsula, the presence of ovigerous

Table 4. Maximal densities of the Asian crab *Hemigrapsus sanguineus* reported along the European and North-eastern American coasts

Location	Observation date	Maximal densities N.ind.m ⁻²	Authors
European sites			
Wimereux, Opal Coast, F	April 2008	11	Dauvin et al. 2009
Dunkirk, Opal Coast, F	April 2008	12	Dauvin et al. 2009
Querqueville, Cotentin, F	August 2008	10	Dauvin 2009a
Querqueville, Cotentin, F	August 2009	16	This study
Gatteville-Phare, Cotentin, F	August 2009	33	This study
La Hougue, Cotentin, F	August 2009	53	This study
North-eastern American sites			
Townsend's and Hereford Inlets, NJ	January 1996	320	McDermott 1998
Long Island Sound Estuary, NY	1998-2001	120	Kraemer et al. 2007
Demerset Lloyd State, MS	August-September 1999	190	Jensen et al. 2002
Long Island, NY	Fall 2000	150	Brousseau et al. 2003
Long Island Sound, NY	2001-2002	350	Kraemer et al. 2007
Long Island Sound Estuary, NY	2002-2005	80	Kraemer et al. 2007
Site 4, Long Island, NY	May-August 2005	44	Delaney et al. 2008

females attested the reproductive ability of *H. takanoi*; however, this species has been shown to have little to no ability to form a significant population in this area. In the same site, *H. sanguineus* had very low population levels: only one single male with a size of 6.7 mm in 2009, compared to three individuals, one male and two females, in 2008. The site may not be favourable for large *Hemigrapsus* populations.

Like in 2008, another non-indigenous marbled crab *Pachygrapsus marmoratus* (J.C. Fabricius 1787) was collected during field sampling in 2009; this species originated in the Mediterranean Sea and in the Atlantic warm temperate zone (Ingle and Clark 2006; Dauvin 2009b) (Annex 1). Five specimens were sampled in a single site at Blainville-sur-mer on 15 July 2009: three males of sizes ranging from 39.0 to 39.8 mm and two non-ovigerous females, size 30.0 and 30.9 mm, respectively. Nonetheless, this species remains rare in this northern extension zone of the English Channel (Dauvin 2009b).

In the following years, it will be interesting to survey the increased abundances along the eastern coast of the Cotentin. The most highly colonised sites - Gatteville-Phare and La Hougue - also presents the opportunity to study the biological cycle of the population along the French coast. More generally, it will be also interesting to survey the beginning of the Asian crab invasion, not only along the French Atlantic and English Channel coast, including English Channel Islands (e.g., Jersey, Guernsey, Alderney), but also along the European coast. No *Hemigrapsus* spp. have as-of-yet been reported on these English coasts. It is sure that all these species have the ability to colonise the favourable rocky shores around the British Islands.

For the moment, the species remains unobtrusive in term of impact on other marine invertebrates and habitats. But as suggested in Dauvin et al. (2009), the potential effect of predation by *Hemigrapsus sanguineus* on the *Mytilus edulis* and *Crassostrea gigas* cultivated in shellfish farms would be the main danger of this invasive species in the future. Shellfish production is highly developed along the French Atlantic coast and is essential for the coastal economy of the Cotentin. It could present a threat to these mussel and oyster farms. For the moment only one recent observation (28 May

2009) attests the presence of some *Hemigrapsus sanguineus* within the mussel farm on Quend-Plage in the north of the Bay of Somme, eastern part of the English Channel (A. Meirlan, personal communication). The *Hemigrapsus* spp. story will continue in the English Channel and in European waters.

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Annex 1. Location for samples of invasive species crabs in the Cotentin, total numbers of collected specimens at each site in 2009
HS - *Hemigrapsus sanguineus*, HT - *Hemigrapsus takanoi*, PM- *Pachygrapsus marmoratus*

Location	Geographic coordinates		Sampling Date	Habitat characteristics	HS	HT	PM
	Latitude	Longitude					
Saint-Jean-Le-Thomas	48°43'56"N	1°33'05"W	14/07/09	Boulders on sandy mud	0	0	0
Granville harbour	48°50'04"N	1°36'20"W	14/07/09	Boulders on muddy gravel	0	0	0
Granville outside harbour	48°49'58"N	1°36'28"W	14/07/09	Boulders on rock	1	0	0
Agon-Coutainville	49°01'29"N	1°36'01"W	14/07/09	Boulders on rock and gravel	2	0	0
Blainville sur mer	49°03'33"N	1°36'47"W	15/07/09	Boulders on rock	2	0	5
Gonneville	49°04'57"N	1°36'43"W	13/07/09	Boulders on rock	2	0	0
Le Senequet	49°05'30"N	1°39'42"W	20/08/09	Boulders on rock	3	0	0
Gouville sur mer	49°06'04"N	1°36'40"W	17/07/09	Boulders on rock	27	0	0
Saint Germain sur Ay	49°12'46"N	1°38'58"W	17/07/09	Boulders on rock	24	0	0
Carteret harbour	49°22'40"N	1°47'06"W	16/07/09	Boulders on muddy gravel	1	0	0
Carteret outside harbour	49°22'20"N	1°48'29"W	16/07/09	Boulders on rock	0	0	0
Dielette	49°32'59"N	1°51'58"W	10/08/09	Large rocks on gravel	0	0	0
Goury	49°42'53"N	1°56'45"W	10/08/09	Boulders on rock	13	0	0
Querqueville	49°40'08"N	1°40'47"W	10/08/09	Boulders on rock	82	0	0
Salines	49°39'28"N	1°38'45"W	10/08/09	Boulders on gravel and rock	17	0	0
Fermanville harbour	49°41'11"N	1°28'24"W	11/08/09	Boulders on gravel and rocks	8	0	0
Gatteville-Phare	49°41'44"N	1°15'56"W	11/08/09	Boulders on gravel and rock	152	0	0
Saint-Vaast	49°35'34"N	1°15'48"W	11/08/09	Boulders on muddy gravel	2	3	0
La Hougue	49°34'30"N	1°16'18"W	11/08/09	Boulders on gravel and rock	202	0	0
Querqueville (m²)	49°40'08"N	1°40'47"W	10/08/09	Boulders on sand	49	0	0
Gatteville-Phare (m²)	49°41'44"N	1°15'56"W	11/08/09	Boulders on muddy gravel	98	0	0
La Hougue (m²)	49°35'34"N	1°15'48"W	11/08/09	Boulders on gravel and rock	160	0	0