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Research Article

Hemigrapsus sanguineus (De Haan, 1835) (Crustacea: Brachyura: Grapsoidea) a new invasive species in European waters: the case of the French English Channel coast (2008–2010)

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Abstract

The unintentional introduction of the Asian shore crab, *Hemigrapsus sanguineus*, along the French coast during the mid 1990s has revealed the problematic effects that invasive species can have on biodiversity, entering into competition with native crab species. This invasion along coastal ecosystems of northern France has become an ineluctable, irreversible phenomenon. The present study describes the distribution and abundance of *H. sanguineus* along the French side of the English Channel from the Cotentin to the Opal Coast on the Dover Strait in spring and summer 2010. The results were compared with those obtained previously in 2008 and 2009 for the same areas and now show that the crab has increased in numbers since its first sighting in 1999. In 2010, the maximal abundance reached 51 ind.m^{-2} in Dunkirk harbour, and 69 ind.m^{-2} at La Hougue in the eastern part of the Cotentin Peninsula. *Hemigrapsus sanguineus* has been sighted all along the southern coastline of the English Channel to the North Sea (approximately 1,500 km). Its high colonisation potential suggests that this brachyuran could continue its invasion in European waters. Therefore a European surveillance network might be necessary to monitor its progression in the north-eastern Atlantic Ocean.

Key words: *Hemigrapsus sanguineus,* Asian shore crab, invasive marine brachyuran, Crustacea, Decapoda, southern coastline of English Channel, North Sea

Introduction

The Asian crab *Hemigrapus sanguineus* (De Haan, 1835) has colonised most of the French English Channel coast since it was first introduced into Le Havre harbour in 1999 (Breton et al. 2002; Dauvin 2009a, b; Dauvin et al. 2009). Subsequently, the species has been recorded all along the north-east European coast, from the western coast of the Cotentin in the English Channel to the North Sea coast bordering the German state of Schleswig-Holstein (Dauvin et al. 2009). In addition, *H. sanguineus* has formed abundant populations at some littoral sites 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, b) and the Dover Strait (Dauvin et al. 2009).

Introduced species may have major effects on the characteristics and dynamics of the colonised ecosystem (Occhipinti-Ambrogi 2007). These often negative effects affect the flux of matter and the trophic chains causing the mortality of some autochthonous species due to great inter-species competition. In the case of *H. sanguineus*, it is suspected that its introduction, as well as another Asian crab (the brush-clawed shore crab *Hemigrapsus takanoi* Asakura and Watanabe, 2005, could reduce the abundance of the autochthonous green crab *Carcinus maenas* (Linnaeus, 1758) in the areas colonized by these species (Dauvin et al. 2009). The introduction of invasive species is often irreversible in the colonised environment (Clout 1998). However, the speed with which an introduced species extends its range varies greatly from one species to another, and also from the first colonized area (McDermott 1998). In the case of *H. sanguineus*, its expansion rate has been estimated at 12 km per year along the eastern coast of the United States (Leppäkoski and Olenin 2000).

According to Valéry et al. (2008) an invasive species has four main characteristics: 1) compe-

tition with autochthonous species; 2) a geographical discontinuity between the native area and the colonised areas; 3) demonstrate a rapid expansion; and 4) rapidly become a dominant species in the colonised areas. The aim of this paper is to illustrate the ability of *Hemigrapsus sanguineus* to colonise and establish populations along the French coast of the English Channel.

Materials and methods

Field sites

Opal Coast

The 160 km of the French coast along the eastern English Channel, from the Authie estuary in the south to the Belgian border and the southern North Sea in the north, is known as the Opal Coast (Figure 1). This coastline is characterized by a succession of sand dunes and rocky shores, extending from Boulogne-sur-mer to Gris Nez Cape and Blanc Nez Cape. Hard substratum with dykes and boulders are also found in the Authie, Canche and Aa estuaries and in the three main harbours of the region: Boulogne-sur-mer, Calais and Dunkirk. As shown in Figure 1, a total of 16 potential favourable crab habitats (Table 1; Appendix 1) were sampled at the beginning of spring (i.e., from the end of March to the beginning of May) 2008 and 2010.

The Cotentin Peninsula

In the Channel, the Cotentin Peninsula includes the northern sector of the 'Manche Department', from Saint-Jean-le-Thomas to Hague Cape (Goury) to the west and from Gatteville-Phare to the Bay of Veys to the east, including Cherbourg harbour (Figure 1). From the Flamanville Cape to Saint-Vaast-la-Houge, the coastline is mainly rocky shores. On the western part of the Cotentin, south to Flamanville, the coastline is essentially composed of sand dunes, except two rocky shore zones (i.e., the Barneville-Carteret and Granville capes). Some rocky outcrops appear in the mid-littoral zone where there is a sand dune habitat. Fifteen sites were sampled in 2008; 19 sites were sampled in 2009 and 2010, including three harbours (Granville, Carteret and Fermanville), three protected sites (Querqueville, Salines and Saint-Vaast), and 13 other sites around the Cotentin Peninsula located in areas with relatively high hydrodynamics (Figure 1, Table 2, and Appendix 2).

Sampling procedure

At each of the sampled sites (Appendix 1 and 2), *Hemigrapsus sanguineus* specimens were counted underneath three groups of 30 boulders in the mid-littoral zone, for a total of 90 boulders per site. This sampling design has been adopted for estimating the abundances of shore crabs (Dauvin 2009a, b; Dauvin et al. 2009). In the sites corresponding to highly colonised zones – three sites in the Cotentin (Querqueville, Gatteville-Phare and La Houge) and three sites along the Opal Coast (Wimereux-Fort de Croy, Dunkirk harbour and Dunkirk outer harbour) – the population density estimations were made using 1m² quadrats, with three replicates being undertaken at each of the sites (Table 6). Rocks and boulders were turned over to collect the crabs; in some cases, it was also necessary to extract the crabs from the burrows that they had dug.

Laboratory observations

Hemigrapsus sanguineus crabs were counted and sexed. Then the carapace width (CW) was measured between the third antero-lateral teeth (Delaney et al. 2008). Class-size histograms were then constructed for 2mm classes.

Results

Distribution and abundance

The 2010 observations confirmed those acquired in 2008 and 2009. Along the Opal Coast, two main areas colonized by *Hemigrapsus sanguineus* could be identified: 1) the sites in the southern part of Boulogne-sur-mer, which were poorly colonised, with only one specimen collected at Berck and 11 at Le Portel in 2010, and 2) the sites from Boulogne-sur-mer to Dunkirk, which were abundantly colonised by *H. sanguineus*, especially the sites with high hydrodynamics exposure outside the harbours (Figure 1, Table 1). In 2010, the western coast around the Cotentin Peninsula remained poorly colonised, whereas the north and eastern part of the peninsula showed more abundantly colonized sites (Figure 1, Table 2).

For the most abundantly colonised sites, Table 3 gives the number of *H. sanguineus* collected underneath 90 boulders throughout the three years of the survey. Except for some sites [i.e., Salines (Cotentin Peninsula) and Dunkirk outer

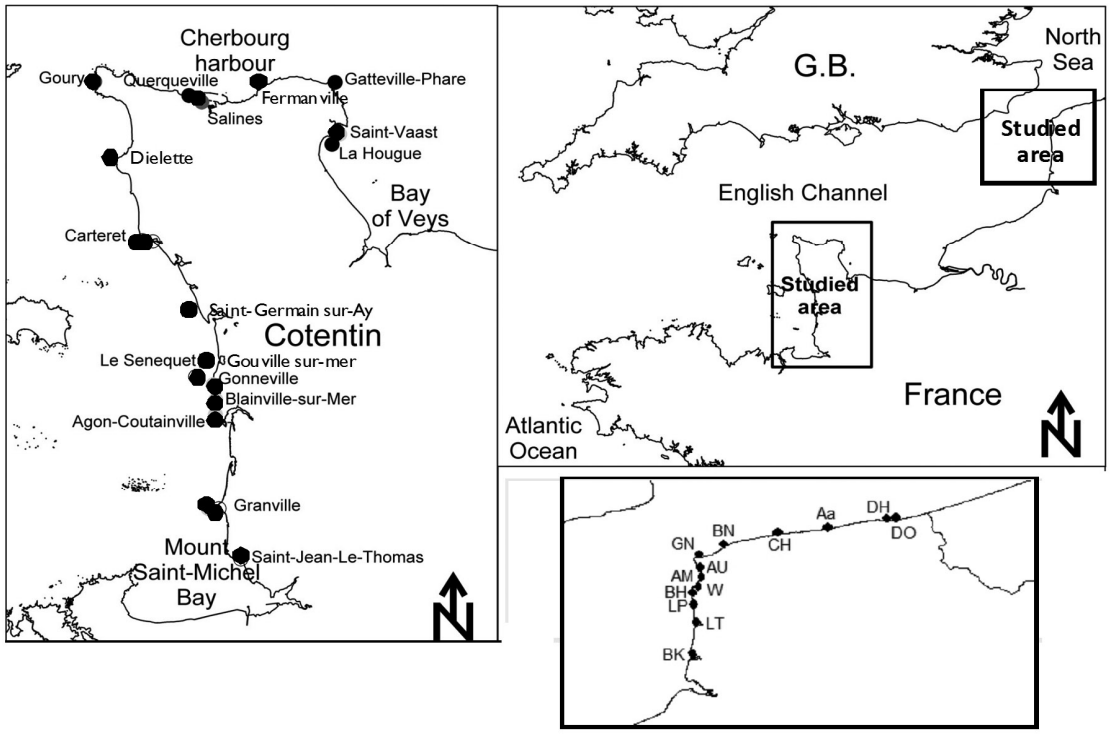

Figure 1. Location of the 16 sites that were sampled along the Opal Coast in April-May 2008 and 2010 (right above, see Table 1 for the abbreviations of the sampled locations) and the 19 sites that were sampled around the Cotentin Peninsula in July-August 2008, 2009 and 2010 (left above) (see table for the abbreviations of the site from the Opal coast).

harbour (Opal Coast)], there was clearly a general regular increase over the years of study of the population abundances. Four high colonisation sites appeared in the English Channel – Gatteville-Phare and La Hougue in the eastern part of the Cotentin Peninsula, and Wimereux – 'Fort de Croy' and Griz Nez Cape on the Opal Coast – where the numbers of individuals underneath the boulders were more than 200.

Density

In the most abundantly colonised sites, the maximal densities per square meter were higher than 50 (i.e., at La Hougue in 2009, at La Houge, Gatteville and Dunkirk harbour in 2010; see Table 6). Like the abundance values, there were regular population density increases at all the sampling sites throughout the survey. A one-way repeated ANOVA showed that there was a significant increase of density with time ($F=15.704$; $d.f=2$; $p<0.0001$, time effect).

Size frequency

An example of the yearly changes of the size-frequency (carapace-width) of *H. sanguineus* at La Houge site in the eastern part of the Cotentin Peninsula for the three years of the survey are shown in Figure 2.

In 2008, the size of sampled individuals ranged from 6 to 32 mm, with the 16–18 mm size class being the most frequent. Three modes could be identified: young individuals around 6–8 mm, medium individuals between 16–18 mm and the largest individuals varying between 28–32 mm.

In 2009, the size of the sampled individuals ranged from 8 mm for the smallest to 38 mm for the largest, with the 20–22 mm size class being the most frequent. There were four main modes: young individuals (8–12 mm), medium individuals (16–18 mm), large individuals (20–22 mm), and the largest individuals (32–38 mm).

In 2010, the size of the sampled individuals ranged from 6 mm for the smallest to 42 mm for

Table 1. Abundance of *Hemigrapsus sanguineus* along the Opal Coast collected on sampling dates during spring 2010 (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. Abbreviations of the sampling sites used in Figure 1 are in parentheses after the site name.

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
Berck – Authie (BK)	04/12	0	1	0	1	0.33±0.58	0	1	0	0
Le Touquet – Canche (LT)	04/12	0	0	0	0	-	-	-	-	-
Le Portel (LP)	03/29	0	0	2	2	0.66±1.2	2	0	-	-
Boulogne Harbour (BH-R)	03/29	7	14	15	36	12.0±4.5	23	13	1.77.	0
Boulogne Harbour (BH-P)	03/29	1	17	0	18	6.0±9.5	14	4	3.50	0
Wimereux Créche (W-C)	04/13	1	4	6	11	3.7±2.5	8	3	2.67	0
Wimereux 'Fort de Croy' (W-F)	01/04	88	91	183	362	124.0±59.8	176	186	0.95	0
Wimereux 'Pointe aux Oies' (W-O)	04/02	14	0	4	18	6.0±7.2	11	7	1.57	0
Ambleteuse (AM)	03/30	8	3	38	49	16.33±18.9	23	26	0.88	0
Audresselles (AU)	03/30	9	50	15	74	24.7±20.7	44	30	1.47	0
Gris Nez Cape (GN)	04/14	50	49	105	204	68.0±32.0	122	82	1.49	9.76
Blanc Nez Cape (BN)	04/14	0	1	0	1	0.3±0.6	0	1	-	0
Calais Harbour (CH)	04/16	1	1	1	3	1.0±0.0	1	2	0.5	0
Grand Fort Philippe (Aa)	04/16	2	2	1	5	1.6±0.6	3	2	1.5	0
Dunkirk outside Harbour (DO)	03/30	37	6	17	60	20.0±15.7	45	15	3.0	0
Dunkirk Harbour (DH)	03/30	26	41	42	109	36.3±9.0	55	54	1.02	5.56
Total					953		527	425	1.24	0.03

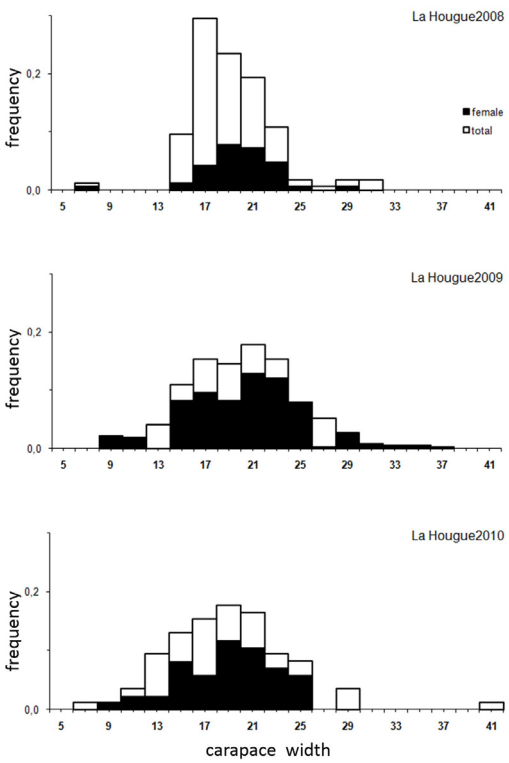

Figure 2. Frequency distribution (in %) of carapace-width classes (2 mm classes) of *Hemigrapsus sanguineus* collected at La Hougue in August 2008, 2009 and 2010.

the largest, with the 18–20 mm size class being the most frequent. For the total population, only one mode can be identified: around 18–20 mm. However, for the females, the size-class histogram shows two modes 13–15 and 18–20 mm. Apart from the maximal length of the largest individuals (males), which increased over the three-year survey, there was no evidence of size increase in the population over time, with probably one, two or three year classes each year.

Figure 3 shows the frequency distribution of carapace-width classes of all specimens collected in 2010 at Le Havre, in 2008 and 2010 along the Opal Coast and from 2008 to 2010 around the Cotentin Peninsula. Two main points should be noted: 1). the individuals collected along the Opal Coast appear to be the smallest of the English Channel populations investigated; 2). there was a summer recruitment of *Hemigrapsus* (Figure 3), but the number of juveniles appeared relatively moderate in comparison with the frequency of large specimens. This suggests that reproduction occurred all summer (given the number of ovigerous females collected at the end of July and beginning of August around the Cotentin Peninsula) and in the beginning of the autumn. This kind of juvenile crab abundance over a long reproduction period may explain the extent of the size class observed in these English Channel populations.

Table 2. Abundance of *Hemigrapsus sanguineus* collected around the Cotentin Peninsula on sampling dates during summer 2010 (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	07/12	0	0	0	0	0	-	-	-	-
Granville harbour	07/12	0	0	0	0	0	-	-	-	-
Granville outer harbour	07/12	0	0	0	0	0	-	-	-	-
Agon-Coutainville	07/11	0	0	0	0	0	-	-	-	-
Blainville-sur- mer	07/11	2	0	0	2	0.66±1.15	1	1	1	100
Gonneville	07/11	1	0	1	2	0.66±0.58	-	2	-	100
Le Senéquet	08/12	1	1	1	3	1±0.0	2	1	2.00	100
Gouville-sur-mer	07/11	2	5	7	14	4.67±2.52	5	9	0.56	100
Saint Germain-sur-Ay	07/29	21	21	23	65	21.67±1.15	30	35	0.86	77.14
Carteret harbour	07/29	1	1	4	6	2.0±1.73	3	3	1.0	100
Carteret outer harbour	07/29	0	0	0	0	0	-	-	-	-
Dielette	08/02	0	0	0	0	0	-	-	-	-
Goury	08/02	10	5	14	29	9.67±4.51	12	17	0.71	76.47
Querqueville	08/02	46	39	32	117	39.00±7.00	43	74	0.58	89.19
Salines	08/02	5	8	11	24	8.00±3.00	8	16	0.33	75.00
Fermanville harbour	08/04	4	8	35	47	15.67±16.86	26	21	1.23	85.71
Gatteville-Phare	08/04	81	67	116	264	88.00±25.23	106	158	0.67	65.08
Saint-Vaast	08/04	1	0	0	1	0.33±0.58	0	1	-	100
La Hougue	08/04	110	105	84	299	99.67±13.80	111	188	0.59	73.40
Total					873		347	526	0.66	71.60

Table 3. Number (N) of *Hemigrapsus sanguin*eus underneath 90 boulders in 2008, 2009 and 2010 at the most colonised sites of the Cotentin Peninsula (in bold) and along the Opal Coast.

Sites	individuals underneath 90 boulders		
	2008	2009	2010
Saint Germain-sur-Ay	-	24	65
Goury	13	13	29
Querqueville	93	82	117
Salines	23	17	24
Fermanville harbour	-	8	47
Gatteville-Phare	83	152	264
La Hougue	77	202	299
Boulogne harbour	3	-	18
Wimereux 'Fort de Croy'	87	-	372
Ambleteuse	26	-	49
Audreselles	25	-	74
Gris Nez Cape	32	-	204
Dunkirk harbour	7	-	109
Outside Dunkirk harbour	66	-	60

At Le Havre in 2010, the size of the sampled individuals ranged from 6 mm to 41 mm. Four modes were clearly indentified: 13–15 mm, 24–26 mm, 32–34 mm and 34 to 41 mm. In this oldest colonized site the populations contained the most numerous number of annual size classes. Population size patterns varied throughout the survey (Table 4). The smallest male was 4.0 mm, while the smallest female was 4.1 mm; the smallest ovigerous female was 10.6 mm, whereas the largest ovigerous female was 34.4 mm and the largest male 41.6 mm. The largest males showed an increase in size over the years on Cotentin Peninsula, demonstrating the population aging process.

Sex-ratio

The male/female sex-ratio displayed a difference between the spring populations along the Opal Coast, where the number of males was higher than the number of females (Ratio> 1), and the summer populations around the Cotentin Peninsula, where the number of females was higher than the number of males (Table 5). The ratio at Le Havre in spring 2010 (0.74) showed similar values to those observed around the Cotentin Peninsula during summer (0.66–0.81).

Ovigerous female

During spring 2008, no ovigerous females were observed along the Opal Coast, while two years

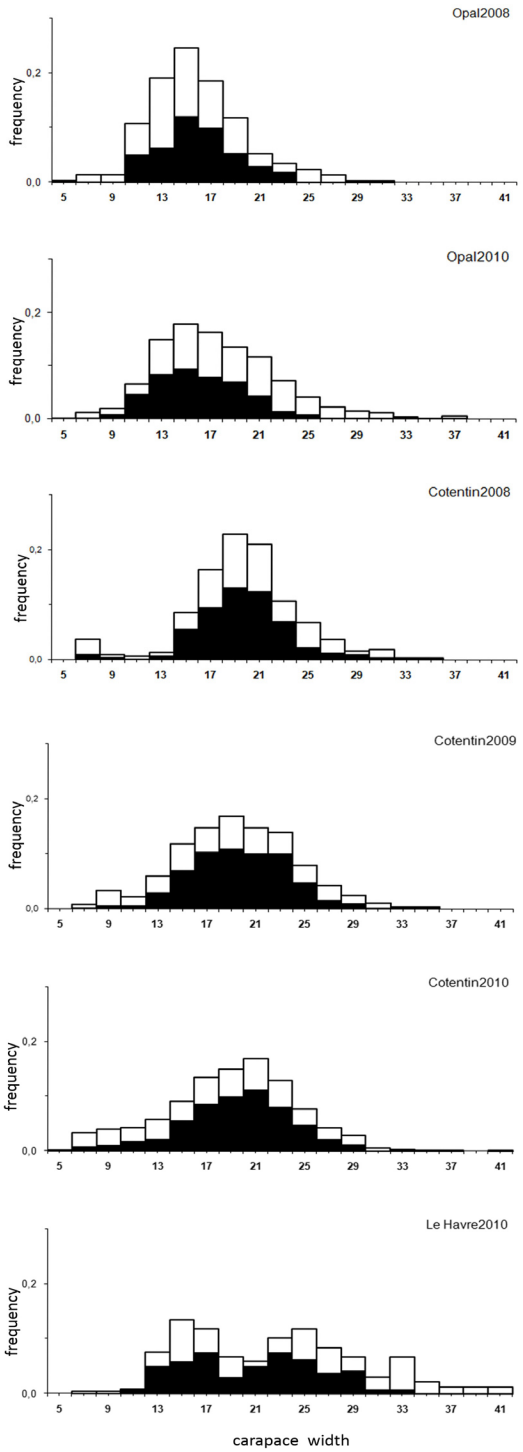

Figure 3. Frequency distribution (in %) of carapace-width classes (2 mm classes) of the *Hemigrapsus sanguineus* collected along the Opal Coast in spring 2008 and 2010, around the Cotentin Peninsula in summer 2008, 2009 and 2010, and in the Le Havre harbour in May 2010.

later, some ovigerous females were observed, demonstrating an extension of the reproduction period. At Le Havre, the frequency of ovigerous females was more significant, representing nearly 10% of the female population (Table 5). During summer, the frequency of the ovigerous females was high in the Cotentin Peninsula population (between 71.6 and 82.4% of the sampled females).

Discussion

The 2010 samples from the Opal Coast and the Cotentin Peninsula confirmed the expansion of the *Hemigrapsus sanguineus* populations along the French side of the English Channel. The 2010 observations demonstrated that there was a general increase in the abundances of the intertidal *H. sanguineus* crab population, which reached densities higher than 50 ind. m^{-2}. While these are the maximum densities measured in European waters, they remain lower than those estimated along the north-eastern American coast (Table 6). In the initial American zone of colonisation, the first specimen was sighted in September 1988 (Williams and McDermott 1990). The density of crabs was so high on Long Island during the early 1990's that fisherman were using them for bait (McDermott 1998). The maximum density observed in 2001–2002 at a site in western Long Island Sound reached 350 ind.m^{-2} (Kraemer et al. 2007). This is seven times higher than the observed crab densities along the French English Channel coast.

At some Channel sites, such as Querqueville and Gatteville, the populations have increased rapidly, doubling in one or two years, while in the Dunkirk harbour, the population has increased five times in only two years. Although changes occur over the three year sampling period, it is not really sufficient to make inferences regarding temporal trends. Only long-term survey will permit to state of the population increases. Probably, the French populations have not reached their maximum densities and could grow over the following years. Following the same colonisation process as along the north-eastern coast of the USA, it could be expected that the *H. sanguineus* population could reach its maximum in four to five years [i.e., 15 years after the first observation in Le Havre harbour in 1999 (Breton et al. 2002)].

Hemigrapsus sanguineus has been sighted along the European coast from the western coast of the Cotentin Peninsula in the English Channel

Table 4. Comparison of the size in mm of the smallest and largest *Hemigrapsus sanguineus* male and female sampled around the Cotentin Peninsula, the Opal Coast and the Le Havre harbour in 2008, 2009 and 2010.

	Opal Coast		Cotentin Peninsula			Le Havre
	2008	2010	2008	2009	2010	2010
Smallest male	4.0	5.1	5.0	4.8	3.8	5.6
Smallest female	9.0	5.9	6.0	6.1	4.1	8.6
Smallest ovigerous female	-	17.9	13.0	11.1	10.6	16.6
Largest female	27.0	35.1	31.0	28.6	28.4	35.4
Largest ovigerous female	-	26.1	31.0	28.6	28.4	34.4
Largest male	26.0	37.1	34.0	35.6	41.6	40.2

Table 5. Comparison of the sex-ratio of *Hemigrapsus sanguineus* (male/female) in the population sampled around the Cotentin Peninsula, the Opal Coast and the Le Havre harbour in 2008, 2009 and 2010.

	Opal Coast		Cotentin Peninsula			Le Havre
	Spring 2008	Spring 2010	Summer 2008	Summer 2009	Summer 2010	Spring 2010
Sex-ratio	1.31	1.24	0.81	0.67	0.66	0.74
% of ovigerous females	0.00	0.03	72.5	82.41	71.60	9.55

to the North Sea coast of the German state of Schleswig-Holstein (Dauvin et al. 2009). It is surprising that no reports have been made in British waters apart the Channels Islands (near the western coast of the Cotentin Peninsula). Two females were sampled during the spring 2009 one at Jersey and the other at Guernsey (Martin 2011). Nevertheless, personal observation of one of the authors of this paper (JCD) during the summer of 2010 from Guernsey and Alderney Isles did not include others specimens; so the species remains rare in the Channel Islands. Similarly, *H. sanguineus* is absent from the French and Spanish Atlantic coasts, while another Asian species (*H. takanoi* Asakura and Watanabe 2005) has continued its progression in the northern Bay of Biscay (Noël and Gruet 2008) and in the western part of the Cotentin Peninsula (Dauvin and Delhay 2010). In the Mediterranean Sea, a single adult male of *H. sanguineus* was recorded in 2003 from the northern Adriatic Sea (Schubart 2003); later Micu et al. (2010) also collected a single male at Tomis Marina on the Romanian coast of the Black Sea. Therefore, it appears that the species has continued its colonisation of European waters, including the southern limits where the species remains for the moment particularly absent. It is possible that a more accurate identification of decapods in the Mediterranean and Black Sea would reveal other sites colonised by *H. sanguineus*. However, the low salinity in the Black Sea could prevent the colonisation by *H. sanguineus* which was probably introduced as an adult along the Romania coast (Micu et al. 2010). So, in spite of continued monitoring for this species in Romania, Bulgaria and Ukraine during 2010, no further occurrences of *H. sanguineus* in the Black Sea could be detected (D. Micu, pers. comm.).

This survey of the English Channel populations shows that *H. sanguineus* is displaying some characteristic features specific to an invasive species. The species is competing with the autochthonous crab *Carcinus maenas*, which has shown low abundance values in the most colonised sites of the northern Opal Coast, while in the southern sites, where *H. sanguineus* has remained rare, the *C. maenas* population is flourishing (Dauvin et al. 2009; this study). The species has rapidly expanded, and since its first sighting in 1999, the species has been sighted all along the English Channel to the North Sea (approximately 1,500 km).

The reproduction period of *H. sanguineus* began in spring; since some ovigerous females were observed both in the Le Havre and Opal Coast populations in April–May 2010. Data basically show that summer is reproductive season. This species displayed a higher number of ovigerous females (> 70%), and a sex-ratio favourable to the female (0.65–0.80) in the summer populations. It has been suggested that the spring mortality affects the males in particular, as the sex-ratio was > 1 in the spring populations on the Opal Coast then < 1 in sum-

Table 6. Maximum number of *Hemigrapsus sanguineus* N ind.m^{-2} estimated at different sites in European and North American waters.

Site	Date	N	Reference
In French waters			
Wimereux 'Fort de Croy'	April 2008	11	Dauvin et al. 2009
Wimereux 'Fort de Croy'	April 2010	29	This study
Dunkirk harbour	April 2008	12	Dauvin et al. 2009
Dunkirk harbour	April 2010	51	This study
Querqueville, Cotentin Peninsula	August 2008	10	Dauvin 2009a
Querqueville, Cotentin Peninsula	August 2009	16	Dauvin 2009b
Querqueville, Cotentin Peninsula	August 2010	21	This study
Gatteville, Cotentin Peninsula	August 2009	33	Dauvin 2009b
Gatteville Cotentin Peninsula	August 2010	63	This study
La Hougue, Cotentin Peninsula	August 2009	53	Dauvin 2009b
La Hougue, Cotentin Peninsula	August 2010	69	This study
In North American waters			
Townsends and Hereford Inlets, NJ	January1996	320	Mc Dermott 1998
Long Island South estuary, NY	1998-2001	120	Kraemer et al. 2007
Demerset Lloyd state, Ms	August-September 2009	190	Jensen et al. 2002
Long Island, NY	Autumn 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

mer population (Table 5). Smallest ovigerous females were sampled in the summer of 2010 than in 2008 and 2009 in the Cotentin Peninsula populations. All these characteristics demonstrate that the species is able to increase its capacity to produce eggs and larvae to ensure colonisation of new sites and maintain high abundance in the colonised sites. The size of the specimens shows that the *H. sanguineus* population had an annual recruitment in the populations along the English Channel and the population matured over time. The largest male was observed in 2010 at La Hougue (41.6 mm). Similarly, in Le Havre, the population exhibited the highest number of annual classes than had been previously recorded (probably four or five for the males) and being indicative of a population that had been established for a long time.

There is a debate with regard to identifying the biological features likely to explain the success of an alien including morphological, biological or behavioural characteristics (e.g., reproductive type, fecundity, and growth capacity, size) of the species. This raises the question: do invasive species possess particular biological features that facilitate their introduction success? According to Sakai at al. (2001) and Kolar and Lodge (2001), the success of an invasive species is related to: a high reproduction potential in their original area where they are abundant; a strong potential for passive or active dispersal of larvae; a reproductive cycle permitting a single individual to establish a population; a large range of food choices; a long life and a large size; a capacity to reproduce rapidly; and a better capacity to exploit the local resources than the native species probably due to the adaptability of invasive species. Devin and Beisel (2007), based on a comparative analysis of invasive freshwater amphipod gammarid species, considered that the success of introduction is more related to ecological rather than biological features; in other words, the characteristics linked to the available habitat (i.e., available ecological niche) would intervene first in the invasive process.

Accumulating information about the earliest colonisation phase of *H. sanguineus* appears to be a future challenge for European scientists. To this end, research began in October 2010 at the Wimereux Observatory to monitor four abundant *H. sanguineus* populations along the English Channel (i.e., La Houge, Le Havre, Wimereux – 'Fort de Croy', and Dunkirk harbour) annually to compare the recruitment strategy of this species. The species' competitive strategy will also be

studied and compared to *Carcinus maenas*. For example, competition for food resources will be studied using stable isotope and fatty acids, as well as competition for space underneath the intertidal boulders located in the upper and middle eulittoral zones.

In addition, it would be useful to obtain results on the effective biological and ecological impact of invasive species, such as the *Hemigrapsus*. Most often, marine invasive species are described as having negative effects on their new environments (e.g., modifying the trophic web and competing with native species – Parker et al. 1999; introducing new diseases – Mooney and Cleland 2001; modifying habitats – Grosholz 2002). Nevertheless, Beisel and Lévêque (2010) have underlined the need to adopt an objective point of view on the impact of introduced and invasive species, which must be validated by scientific observations. They also recommend that benefits and threats must be verified without a prejudiced position. In the particular case of *H. sanguineus*, the fact that the species colonizes essentially the high level of the eulittoral, where the biodiversity and invertebrate biomass are low could be advantageous for this intertidal area if *H. sanguineus* serve as food resources for birds and fishes. Conversely, if the species occupies a large range of the eulittoral and the shallow subtidal zone and consumes mussels and oysters cultivated in shellfish farms as suggested by Dauvin et al. (2009), this could be a threat to shellfish production in the future.

A comprehensive overview of the present distribution of *H. sanguineus* along the Atlantic and Channel coast of France, similar to those published on the oriental shrimp *Palaemon macrodactylus* Rathbun, 1902 is needed. After its first sighting in 1998 in the Gironde estuary during the 2007–2010 period this shrimp has been reported from the Slack estuary in the north to the Bidassoa estuary in the south (Lavesque et al. 2010), which shows its rapid expansion. These authors suggest that the hydrodynamic characteristics along the French coast are sufficient to support the hypothesis of passive larvae or adult transport to colonise discontinuous transitional water systems. Such data should be compiled in the future for the case of *H. sanguineus* but also for the second invasive Asian crab species *H. takanoi*. Based on such information the future spread of both species may be predicted.

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Supplementary material

The following supplementary material is available for this article.

Appendix 1. Locations of *Hemigrapsus sanguineus* specimens along the Opal Coast and in Le Havre harbour.

Appendix 2. Locations of *Hemigrapsus sanguineus* specimens around the Cotentin Peninsula.

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